PRR

IMPACT

of science on society

Vol. VI, No. 2
June 1955

[A] Price per copy: $ .50; 2/6; 125 fr.

JUL 12 1955
PERIODICAL READING ROOM

IN THIS ISSUE:

Man's Responsibility to his Genetic Heritage
by MOGENS WESTERGAARD

Some Problems in Underdeveloped Areas
by E. W. GOLDING

Pages from the Past: Tocqueville on Science in Democracy

IMPACT *of Science on Society*
quarterly

Annual subscription:
[A] $1.75; 9/6; 450 fr.

Any of the National Distributors listed at the end of this number will accept subscriptions; rates in currencies other than the above will be supplied on application to the National Distributor in the country concerned.

When notifying change of address please enclose last wrapper or envelope.

© UNESCO 1955
NS 55 I 19A

UNITED NATIONS EDUCATIONAL, SCIENTIFIC
AND CULTURAL ORGANIZATION
19 Avenue Kléber, Paris-16e, France

Contents

MAN'S RESPONSIBILITY TO HIS GENETIC HERITAGE
by MOGENS WESTERGAARD 63

Genetics, because of its bearing on evolution mechanics, holds the key to most of the biological problems which should be the concern of political leaders and economic planners. The genes and chromosomes which we received from our ancestors should be treated not as our own property, but as the property of our species and of our descendants. Never has man's responsibility to his genetic heritage been put to a more severe test than it is in the atomic age, for ionizing radiation, through its damaging effect on the genes, can change the course of man's biological evolution.

SOME PROBLEMS IN UNDERDEVELOPED AREAS
by E. W. GOLDING 89

The author discusses the aims and means of development, certain common problems which arise in most underdeveloped areas, and the role of technical assistance and of exchanges of information. He then reviews development plans and problems in some countries recently visited, i.e. the Aden Protectorate, Israel, Haiti, India and Pakistan.

PAGES FROM THE PAST: TOCQUEVILLE ON SCIENCE IN DEMOCRACY 110

This selection from Alexis de Tocqueville's Democracy in America *consists of the two chapters of volume II in which the author discusses the influence of democracy on the development of science. Although written in 1840, this text has withstood the test of time remarkably well, and much of what de Tocqueville has to say about science in democracy is still relevant to the conditions of today.*

CONTENTS OF PRECEDING ISSUES

Vol. V, No. 1, March 1954
Science and the Prevention of Crime,
by OLOF KINBERG
Local Energy Sources for Underdeveloped Areas,
by E. W. GOLDING
The Right to Scientific Property: a Unesco report

Vol. V, No. 2, June 1954
Scientific Progress and the Evolution of International Law,
by CHARLES ROUSSEAU
The Human Element in the Application of Science,
by J. R. GASS
Photosynthesis and Algal Culture,
by D. NEVILLE-JONES
Machines and Men,
by R. M. GOODWIN

Vol. V, No. 3, September 1954
Science and the Press,
by WILLIAM E. DICK
Organizing for Applied Research in the Civilian Field,
by J. KNOX
Scientific Calvinism,
by A. C. ALLISON

Vol. V, No. 4, December 1954
Scientific and Social Aspects of Modern Medicine,
by HENRI PÉQUIGNOT

Vol. VI, No. 1, March 1955
Scientific Thought and Revolutionary Movements,
by DAVID THOMSON
The Possibilities of Soilless Cultivation,
by J. W. E. H. SHOLTO DOUGLAS
Blood Groups and Racial Groups,
by A. C. ALLISON

MAN'S RESPONSIBILITY TO HIS GENETIC HERITAGE

by

MOGENS WESTERGAARD

Dr. Westergaard is Professor of Genetics at the University of Copenhagen and author of several books on genetics. His particular fields of interest are the genetics of sexuality, microbial genetics and chemical mutagenesis.

Some day it will probably be realized that one of the most important scientific achievements of this century has been the formulation of the modern theory of biological inheritance, known as the 'gene-chromosome theory'. For it will be seen that this theory has revolutionized not only the biological sciences, but also technology, medicine, and even the humanities.

Biology, because a fundamental biological problem, that of the mechanism of organic evolution, can now for the first time be seen from a sound, scientific point of view.

Technology, because our recently gained knowledge about the mechanism of evolution has made it possible for man to direct much more efficiently than before the evolution of those cultivated plants and domestic animals whose breeding is the basis of human civilization. Genetics has thus already played, and will in the future play increasingly, a dominant role in the battle against starvation, which is today the main problem for two-thirds of the world's population. It is only necessary to mention one outstanding achievement—the development of the hybrid corn production which began in the United States in the early thirties—to illustrate the vital role of genetics in this connexion.

In medicine, the genetic theory of evolution tells us to what extent we may be able to guide and control the evolution of our own species; and, even more important, we also learn about the limitations of such possibilities. Moreover, because of the damaging effect of ionizing radiation on genes, genetics can point out the dangers to which the unrestricted use of atomic energy may expose mankind and write the *Mene Tekel* on the wall. It may also be mentioned that one of the most important medical discoveries of recent years, antibiotics, would have been almost worthless without the collaboration of genetics. Thanks to Professor Muller's discovery, in 1927, that X-rays could induce mutations, it became possible to improve the yield of the moulds which produce penicillin. Through a number of mutational steps, induced by radiation, it has been possible to obtain a thousand-fold increase in penicillin yield. Antibiotics could thus be produced at prices within everyone's reach.

Then there is the impact of genetics on the humanities. In ancient Greece the philosophers wrote over the entrance to the Delphic oracle: 'Know thyself'. We must consider this a challenge to solve the equation which the Danish geneticist Wilhelm Johannsen established at the beginning of this century: the individual, the *phenotype* as he called it, is the product of the *genotype* (i.e. the genetic component) and the environment. We must find out what role these two components—nature and nurture—play, not only in shaping the individual itself, but also in shaping our societies, our populations, and our species. Although we are far from solving this equation, Johannsen provided us, for the first time, with an adequate tool which put the solution within our reach.

In the following paragraphs we shall discuss only a few of the above aspects. First, however, we must briefly summarize some of the fundamental concepts of the gene-chromosome theory, and of the genetic theory of evolution.

THE ELEMENTS OF GENETICS

The modern theory of biological inheritance is based upon two very simple concepts: one is the concept of the gene, the other is Johannsen's distinction between genotype and phenotype.

The gene hypothesis was first introduced into biology in order to explain the results of some very simple crossing experiments in which the inheritance of well defined characters was followed through two to three generations. Such experiments were first carried out by the Austrian monk, Gregor Mendel, and the basic principles of inheritance are therefore often referred to as Mendelism. The fundamental idea is that inheritable characters are transferred from parents to offspring indirectly through *genes,* which segregate into the germ-cells or gametes (reproductive cells) according to very simple laws. Later, Morgan and his collaborators in the U.S.A. showed that these genes were localized in the chromosomes of the cell nucleus, each gene occupying a specific position (locus) in a specific chromosome. By fertilization, each individual receives two sets of chromosomes, one set with the egg from the mother, the other set with the sperm from the father. All cells derived from the fertilized egg therefore contain two sets of chromosomes. Correspondingly, all such cells contain two sets of genes, each gene of one set having its counterpart, its so-called *allele,* in the other set. During the formation of germ-cells the chromosome number is reduced to half through a rather complicated process called reduction division or *meiosis.* The segregation of the genes into the germ-cells, as inferred from crossing experiments, is explained by the segregation of the chromosomes during the reduction division. The student who wants to understand the principles of Mendelian

inheritance must therefore first understand the behaviour of the chromosomes during the reduction division. Having grasped these rather complicated facts, he can read the principles of Mendelian inheritance, the potentialities as well as the limitations of the mechanism, like an open book.

In most cases the two allelic genes which a child receives from its two parents do not express themselves equally. If, for instance, a child has received the gene *B* for brown eyes from one of the parents, and the gene *b* for blue eyes from the other, the genetic constitution of this child with regard to eye colour will be *Bb*. Such a child will have brown eyes because the gene for brown eyes is *dominant* over the gene for blue eyes. The latter is referred to as the *recessive* gene. Dominant genes are usually designated by capital letters, recessive genes by small letters. In order to have blue eyes the child must receive the gene *b* from both parents, because only the *bb* constitution will give blue eyes. This, however, does not mean that both parents of a blue-eyed child must have blue eyes. As a matter of fact, they may often both have brown eyes. In this case both parents must have the genetic constitution *Bb*. According to the so-called Mendel's First Law, half of the gametes of each such parent will have the gene *B*, the other half the gene *b*. By random fertilization between eggs and sperm containing *B* and *b* in equal proportion, four types of individuals will be produced. *B* eggs fertilized by *B* sperms will result in brown-eyed *BB* children, one-quarter of the offspring on an average having this constitution. The second combination is a *B* egg fertilized by *b* sperm, or a *b* egg fertilized by *B* sperm. This will give brown-eyed children of the constitution *Bb*, and this group will comprise on an average half of the offspring. Finally *b* eggs may be fertilized by *b* sperms, and will give blue-eyed children, which will constitute on an average one-quarter of the offspring.

Individuals which have two identical alleles (*BB* or *bb*) are called *homozygotes*, whereas those with two different allelic genes (*Bb*) are called *heterozygotes*. One of the most important consequences of genetic dominance is that a gene for a certain character, e.g. blue eyes, may be present without manifesting itself phenotypically. Brown-eyed people of the constitution *BB* and *Bb* look alike, they are 'phenotypically identical' with respect to eye-colour. Nevertheless only the latter type—the heterozygotes (*Bb*)—can produce blue-eyed offspring, namely by a blue-eyed *bb*, or a brown-eyed *Bb* partner. We do not know the genetic constitution—the genotype—of a person until we have seen the offspring. Only when a brown-eyed person begets a blue-eyed child, can we say that his genetic constitution with respect to eye-colour is *Bb*. Likewise, a certain number of 'normal people' may be heterozygotes with respect to recessive genes which in certain combinations may give rise to mentally or physically defective children, but the presence of these recessive genes may be unknown until we see the offspring.

The gene is both a unit of determination and a unit of segregation. The

above example demonstrates the very simple principle underlying Mendelian segregation, expressed in Mendel's First Law, which states that half of the gametes of the heterozygote *Bb* will carry only *B* and the other half only *b*, whereas the body cells, derived from the fertilized egg-cell (the zygote), will carry both.

Our second example will demonstrate the principle of Mendelian recombination, which is expressed in Mendel's so-called Second Law: the Law of Independent Assortment (of different genes). Certain people perceive the taste of a chemical compound called phenyl-thio-carbamide (PTC) as extremely bitter, whereas others, in all countries, are unable to taste it at all. This difference in taste sensitivity is inherited in the same simple way as the difference in eye-colour. Positive taste reaction is inherited through a dominant gene (*S*), whereas negative taste reaction is inherited through a recessive gene (*s*). The genetic constitution of 'tasters' is *SS* or *Ss* whereas 'non-tasters' will be *ss*. Hence if a brown-eyed taster and a blue-eyed non-taster have offspring, the genetic constitution of the children may be *SsBb*, and they will be brown-eyed tasters. However, in accordance with Mendel's Second Law, such people will form four different types of germ-cells, namely *Bs*, *BS*, *bS* and *bs* in equal proportions. There are 16 different combinations between such eggs and sperms, and among the zygotes will appear, for instance, some with the constitution *BBss*, others with the constitution *bbSS*. The first will produce a brown-eyed non-taster, the second a blue-eyed taster. Thus among the offspring of two people, one a brown-eyed taster and the other a blue-eyed non-taster, there will appear among the grandchildren people with the characteristics of their grandparents combined in a new way, the eye-colour of the grandmother combined with the taste reaction of the grandfather and vice versa. This is due to a reshuffling of the genes, which is a consequence of Mendel's Second Law. This reshuffling is an exceedingly effective mechanism of variation which is responsible for most of the genetic variation between parents and offspring, and among individuals of the same species.

Genotype and Phenotype

When Johannsen first tackled the problem of nature and nurture, he knew about the laws of Mendelian inheritance. When he stated that the genotype plus the environment makes the phenotype—the individual—he realized that it would be very difficult to evaluate the relative contribution of heredity and environment, because both components vary from one individual to another. However, in certain cases it is possible to study the reaction of individuals with identical genotypes, i.e. with the same heredity, in different environments. Such individuals may be obtained from so-called clones, i.e. the group of plants which are reproduced vegetatively (asexually), because genetic

variation arises only through sexual reproduction (with the exception of mutations). In man, uniovular twins provide such individuals. Uniovular twins come from one fertilized egg which is separated into two embryos during cleavage. They therefore have identical genetic constitutions. All differences which may exist between such twins must therefore be due to the environment. However, from this it does not necessarily follow that all similarities between uniovular twins are due to heredity. This is a pitfall into which not a few geneticists have fallen.

The study of variation in uniovular twins—where especially valuable information has been obtained from investigations of such twins reared apart—combined with the study of human pedigrees, has clearly shown that the question about the relative contribution of nature and nurture in shaping man's phenotype is meaningless unless it is reduced to specific aspects. If one asks, for instance, whether genes or environment determine man's blood type, the answer is clearcut, because the blood type is determined only by the genotype—actually by a few major genes which are inherited in a very simple way. If on the other hand the question is whether, for instance, language is determined by the genotype or by the environment, the answer is already more complicated. What is genetically determined in this case is the ability to speak, and the capacity to learn to speak, but the environment determines which language will be spoken. There are genes for making sounds, for perceiving sound, etc. (although we know very little about their inheritance), but there are no genes for speaking English, Russian or Chinese. If the question concerns, for instance, man's individual intellectual achievements, the problem becomes still more complicated. We can perhaps best express the situation by saying that nature (the genotype) provides the potentialities, and the environment the opportunities—for good or bad. We could also say that the genotype sets the upper as well as the lower limits for man's achievements, for the individual as well as for the species, but that the environment determines the level of achievement within these limits. A more precise statement of the problem is given in the following quotation from two American geneticists, Dobzhansky and Holz:

> Genes produce not characters but physiological states which, through interactions with the physiological states induced by all other genes of the organism and with the environmental influences, cause the development to assume a definite course and the individual to display certain characters at a given stage of the developmental process.[1]

The Inheritance of Acquired Characters

When Johannsen studied the integration of heredity and environment he was not primarily interested in the problems stated above. What he wanted to

1. *Genetics*, 28, 295, 1943.

investigate was the reaction of the genotype—not the phenotype—to the environment. He wanted to know whether the old Lamarckian doctrine about the inheritance of acquired characters was true or not. We know that the environment can change the phenotype to a very great extent, but are these changes inherited? This question cannot be answered from the study of clonal variation. To answer it, Johannsen realized that he would have to work with material in which not only all individuals were genetically identical—as they are in a clone—but in which parents and offspring of successive generations were genetically identical. In genetic terminology this meant that they must be homozygotes with respect to all genes. These are the so-called 'pure lines', which can be obtained from self-fertilizing plant species. Johannsen's investigation of variations in pure lines, which he carried out over many generations, convinced him as well as his contemporaries that acquired characters, which we now call *modifications,* are not inherited; the Lamarckian doctrines had to be rejected. The genotype does not respond directly to the environment. (We shall discuss this problem in a different context, in connexion with the genetic theory of evolution.)

Mutations

The genes are of course not completely stable. Sometimes they undergo certain changes which are called mutations. The mutations provide a primary source of genetic variation. Through the Mendelian mechanisms of segregation and recombination, the mutated genes are reshuffled and recombined, thus establishing what we may call a secondary level of variation. The problem of mutations will be dealt with more thoroughly in the following paragraphs.

By introducing the concept of the gene, by linking the genes with the chromosomes of the cell nucleus, by introducing the concepts of genotype and phenotype and the concept of mutations, genetics has been able to give a satisfactory explanation of all the main facts and problems of biological inheritance. This is a most remarkable achievement for no more than fifty years of research. It is perhaps equally remarkable that the full import of these revolutionary discoveries has been realized and appreciated by so few people.

THE GENETIC THEORY OF EVOLUTION

The genetic theory of evolution deals with the mechanism by which organic evolution has taken—and is taking—place. It is a problem with which Darwin had already occupied himself very much. Obviously such a theory cannot be adequately formulated unless the mechanism of biological in-

heritance is known. And it is a high tribute to Darwin's genius that even without knowing the principles of Mendelian inheritance, he struck so close to the truth.

The genetic theory of evolution must be able to explain: (a) how genetic variation arises; (b) how this variation becomes sorted out into the discontinuous system of units which taxonomy describes as species, races, varieties, etc.; (c) the adaptation of the species to the environment: how they have managed to survive in an often remarkably specific environment.

The genetic theory of evolution has been able to explain the above facts by means of a system which, like the principles of inheritance, is basically very simple—as long as we confine ourselves to the more general outlines. Genetic variation arises primarily through mutations. These sometimes involve changes in single genes only, in other cases rather complex re-arrangements of the chromosome material. Secondarily, genetic variation arises through the reshuffling of the mutant genes by means of the Mendelian mechanism of segregation and recombination. This answers the first of the three questions. This variation is then sorted out by means of natural selection in the old Darwinian sense of the word. Hence discontinuous variation as well as adaptation are both brought about by natural selection. It is the response of different genotypes to the discontinuous environment.

There are two aspects of the genetic theory of evolution which we must discuss in some detail.

Selection does not act on the individual genes, but on gene combinations, i.e. on genotypes. The fitness, or survival value, of specific genotypes must be considered in relation to the environment, otherwise the problem has no meaning. Certain genotypes may have a high survival value in one environment, but they may be complete failures in another. Genes and genotypes which have a high selective value in a certain environment will multiply faster than those which have a lower selective value, and thus the most fitted will survive.

The second point which must be stressed is the struggle between fitness and plasticity. All populations have a concealed genetic variability in the form of a small proportion of genes which have a low selective value for the population in its present environment, but which may have a higher selective value in a changed environment. Such genes are constantly introduced into the population by mutations, but they are kept down to a very low concentration by means of natural selection. The existence of this concealed variation can easily be demonstrated in the crossbreeding of animals and plants, by subjecting them to artificial inbreeding—for instance by brother and sister crossing. This hidden variability gives the populations a margin of safety. It gives them a genetical plasticity which may secure their survival if the environment changes. However, this concealed genetic variability is felt as a genetic load, the immediate effect of which is to reduce the fitness of

the populations, and natural selection will tend to keep it down to a minimum. It is the price which every species must pay for long-term survival. Human populations also carry such a genetic load, mostly in the form of recessive genes which are occasionally segregated out as homozygotes. The frequency of the homozygotes (*aa*) will depend mainly upon the concentration of the recessive genes in the populations. The problem of this genetic load (a term which Muller has recently introduced) is one about which geneticists have become very much concerned on the threshold of the atomic age.

This brings us to the consideration of man's unique place in the biological system.

THE EVOLUTION OF MAN

As we have seen, animals and plants survive by adaptation to the environment. This adaptation is achieved through natural selection of the best fitted genotypes. However, through a selection process which has gone on for probably not much more than 100,000 years, man has gradually invented a new method for survival—and he is the only species to have done so. Instead of adapting himself—as animals and plants do—to the environment, he adapts the environment to meet his needs. Man's unique power to transform nature is of course determined biologically, i.e. genetically. How this new trend in evolution originally started, we do not know; but the beginning must have been a gradual selection of genes and gene constellations which improved the efficiency of the human brain. Man has not only been able to control inorganic nature, but also other species—by domesticating certain wild animals and plants. During the last hundred years—the period known as the industrial age—man's ability to transform and adapt nature has undergone a revolution; and only 15 years ago, thanks to the ingenuity of a small group of physicists, yet another revolution was accomplished through the control of atomic fission. If the invention does not destroy the inventors, almost unlimited possibilities for further progress will be opened up. However, the industrial and scientific revolution of the last century, and especially of the last decade, raises a number of problems concerning man's biological evolution which it would be most unwise, and even disastrous, to disregard. In all these problems the genetic aspect is dominant. It is therefore fortunate that this great revolution in atomic physics took place at a time when man, for the first time in his history, had gained sufficient knowledge of the mechanisms of heredity and evolution to be able to foresee some of the biological consequences of the atomic age.

Let us once more consider the genetic structure of the human populations in relation to the struggle between fitness and plasticity, i.e. the problem of the concealed genetic variability. Professor Muller has recently illustrated

this principle by a very illuminating picture.[1] Let us suppose a firm starts to build up a new fleet of trucks. It may buy for instance two new trucks each year. The number of trucks will increase, until some of the old trucks wear out. The fleet of trucks will remain constant, i.e. equilibrium will be reached, when the elimination of old cars and the provision of new cars are balanced. If each car, for instance, lasts three years, it can easily be calculated that with two new cars per year, the firm will constantly have six cars in operation. If f is the number for which equilibrium is reached, u the number of cars bought each year, and p the endurance of the cars, then

$$f = u\,p$$

It is obvious that this fleet of trucks may be increased in two different ways: by increasing the duration of the life of the cars, or by buying more cars per year. If, for instance, the cars last six years instead of two, 12 cars will be in operation (2×6). If the firm buys four cars per year instead of two, it will have 12 cars if each lasts three years, and 24 if each lasts six years.

In order to get from this picture to that of man's genetic load, we must think of u as the mutation pressure, and of p as the reciprocal value of the selection pressure. The old cars (mutations) are eliminated by natural selection, and the shorter they last, the stronger is the selection pressure. In each generation a number of mutant genes is introduced into human populations —as into populations of plants and animals—through spontaneous mutations. These mutations are added to those which have occurred in previous generations. In each generation a number of these genes is eliminated through natural selection, which tends to keep this genetic load down to a minimum. If we express the efficiency of the selection pressure by the selection coefficient s, then

$$p = \frac{1}{s}$$

and our formula for the equilibrium now reads

$$f = \frac{u}{s}$$

We may thus increase the genetic load of mutations either by increasing the mutation rates of the human genes, or by decreasing the selection pressure, i.e. by increasing the life expectancy of the mutant genes.

1. H. J. Muller, 'Our Load of Mutations', *American Journ. Human Genetics*, 2, 111, 1950.

To sum up, the genetic structure of human populations is determined by the frequencies of the human genes, which in their turn are determined by the forces of evolution. The populations are in equilibrium, i.e. the gene frequencies remain constant, when natural selection and mutation pressure are in equilibrium (we will leave out of this discussion other evolutionary forces which may also affect genetic equilibrium). Our task is now to investigate whether the conditions of modern civilization created by the scientific and technical revolution affect genetic equilibrium—the composition of the human gene pools—and if so, in what way. This means, primarily, that we must investigate whether our 'way of life' interferes with either natural selection or mutation pressure, or with both. If it does, then it affects the course of human evolution—because, in genetic terms, evolution means that the genetic equilibrium changes.

However, it is impossible to deal with these—or any other—human problems solely from a biological standpoint. We cannot disregard the ethical point of view, because the course of human evolution must be evaluated by an attempt to integrate its biological, ethical, economic and political aspects.

THE ETHICAL ISSUE

The structure of human societies is determined not only by biology and economy, but also by certain ethical concepts. Long before man knew the laws of heredity he recognized his responsibility to his fellow men, and especially towards those who were unfit or helpless. This concept of responsibility has undoubtedly evolved throughout history. It has gradually extended from family or tribe to fellow citizens or those who belong to the same race. Unfortunately, man sometimes feels a higher responsibility towards those who share his skin-colour, his religious or political beliefs, than towards those with different skin-colour, religion or political views. Still more unfortunately, this responsibility is sometimes perversely transformed into a feeling of duty to destroy those who do not share the same taboo. Increasingly, however, people are extending their sense of responsibility to include the whole species.

With the coming of age of genetics, it is now possible to define our ethical obligations towards our fellow men much more precisely than before, because we can specify our responsibilities towards the human phenotypes as well as towards the human genotypes. Two quotations show how prominent geneticists appreciate the ethical aspects of their science. The first is from a statement by a number of America's leading geneticists (Muller, Dobzhansky, Demerec, Levine, Schrader and Snyder):

At the present level of genetic knowledge, we cannot improve the genes with which we are born, and there is little we can do to determine which genes we pass on to our children. But we can improve the manifestations of our own genes and those of other persons so that the best possible phenotypes are produced. The control of the manifestation of human genes is, of course, possible only by proper manipulation of the environment. The implications as regards medicine, especially preventive medicine, are obvious. As Dobzhansky of Columbia University has put it: 'medicine is the science of management of the human phenotype'.[1]

The second quotation is from a paper on 'The long-term genetic hazards of atomic energy' by the British geneticist, Professor Kenneth Mather of Birmingham University:

As Muller has emphasized, we are, in a real sense, only trustees of our own germ plasm. It will outlast us, and we must treat it as the property not of ourselves alone but of all our descendants and indeed of the species as a whole.[2]

It is natural to discuss these two aspects of what might perhaps be called 'gene ethics' separately, because the first statement deals mainly with problems related to medical science, whereas the second is related to nuclear physics.

HORMONES, DRUGS AND GENE-FREQUENCIES

The statement of the American geneticists recognizes first the fact that both the individual phenotype and the population phenotype evolve from the interaction of genes and environment. It also recognizes that our ability to handle human genes is limited if compared to our ability to influence the expression of the genes through manipulating the environment. This is a very sound statement, and it should not surprise us, since man's ability to handle his environment has developed and improved over thousands of years, whereas it is only in the last thirty or forty years that he has begun to understand something about his own genes. Hence our first ethical responsibility is to give the human genotypes the best possible environment.

A major trend in human evolution, particularly in its later stages, is undoubtedly towards greater variability—man is without question the most polymorphic of all species. The variability which a species manifests is probably mainly a reflection of the range of environments in which it can survive. Man, by virtue of creating his own environment, has been able to create more and more ecological niches, which are fitted to meet the genetic requirements of more and more different genotypes. Hence, our increasing polymorphism. In fact, man shows one of the most characteristic features of

1. See L. H. Snyder, *The Principles of Heredity*, Boston, 1951.
2. See A. Haddow (ed.), *Biological Hazards of Atomic Energy*, Oxford, 1952.

domestication: he who has domesticated so many animals and plants has in the course of this process himself become a domesticated animal.

In the last decades, the great progress in medical science has speeded up this evolutionary trend towards increasing variability, because hormones, vitamins and antibiotics have created many new ecological niches in which those who were previously unfitted may now survive. For instance, the discovery of the hormone insulin in 1927 created the 'insulin niche', in which those who suffer from diabetes may survive. The discovery of the liver cure against pernicious anaemia created the 'liver-pill niche', etc. However, in most cases we cannot specify the new ecological niches as precisely as in the above cases. Sulpha drugs, antibiotics, etc., all contribute towards improving the environment for those who are less fitted to survive by their own means.

Many people are concerned about this progress in medicine, especially preventive medicine, and wonder how it will affect the genetic structure of human populations. In dealing with this issue, we must keep two problems apart. The first concerns those factors which will increase life expectancy, so that people with inherited potential defects may survive to reproductive age. The second concerns the factors which increase life expectancy beyond reproductive age. The genetic implications of the first factors are obvious. However, the second problem also has its genetic aspects, as we shall see below.

Let us base the discussion of the first problem on a concrete example, that of diabetes.

Although the genetics of diabetes is not yet fully understood, a great number of cases may be explained by a hypothesis proposed by Harris. According to this hypothesis, diabetes shows recessive inheritance; in homozygotes (*dd*) a severe form develops, and before insulin was discovered such diabetics died within a year. Even with insulin, their life expectancy is not restored to normal. In heterozygotes (*Dd*) the milder form develops, but only in certain adverse environments, for instance when the diet contains too much sugar. Hence the severe form is determined exclusively by heredity, the mild form both by heredity and environment. The life expectancy and, more important, the fertility of diabetics has undoubtedly increased. When insulin was discovered, questionnaires were sent out to Danish physicians in order to estimate the demand for insulin. At that time—in 1927—there were 4,250 diabetics, or 12 per 10,000 of population. In 1946 this number had increased to 17,223, or 43 per 10,000 of population. With the reservation that it is difficult to compare medical statistics so many years apart, because both the technique of diagnosis and the method of collecting statistical data have improved, the figures nevertheless indicate a very great increase over a period of only twenty years. Part of this increase is undoubtedly due to some unspecified change in the diet, which has increased the manifestation in the heterozygotes. However, at least a part of the increase must undoubtedly be

ascribed to an increased frequency of the diabetes gene (*d*), due to the introduction of insulin. Because medical science has created the very specific insulin-niche, the selection pressure against the gene has decreased, and the concentration of the gene in human populations has increased and will probably continue to do so for some time to come. Undoubtedly it costs a considerable amount of money to maintain the fitness of diabetics, and in the modern welfare state this is considered an economic obligation, not so much for the diabetics and their families as for the community. The cost to Denmark of restoring diabetics to at least partial fitness amounts to several million kroner per year.

A similar situation probably exists with regard to a number of other human genes. Medical science has improved the manifestation of many genes by improving the environment. Consequently both the individuals who carry these genes and the genes themselves live longer, and the gene frequencies rise—at a not inconsiderable cost to the community.

This has caused many people to fear that human populations will degenerate biologically—and collapse economically—because of loss of fitness. The author does not share this pessimism—at least not at the medical level of the problem—for a number of reasons.

In the first place, the biological concept of fitness can be easily misconstrued. Fitness has seldom an absolute meaning, and must be considered in relation to the environment. Probably most of the genetically handicapped people which medical skill can keep alive under the conditions of the modern welfare state would have a very low survival value in a primitive community, where they might become an intolerable burden. However, they may render exceedingly valuable services to our highly developed industrial communities. As a matter of fact, probably very few of the people who render the greatest services to the modern community would be successful in a primitive one. We must then discuss fitness in relation to the present structure of our society, not to the conditions prevailing two thousand, two hundred or even twenty years ago.

There is a second point which, to the author, is perhaps the most important. Although some do not want to admit it, all people are not making an equal contribution to the community, and the differences in achievement are independent neither of the genotypes nor of the environment. By increasing the life expectancy of, for instance, diabetics, we may keep for the service of our communities, and perhaps even of our species, a person, be he an outstanding artist, politician or scientist, who may repay to the society a thousandfold the cost of insulin for all its diabetics. The author knows of one deaf-mute who is an outstanding plant breeder, and whose contribution towards increasing the crop-yields of his country has probably many times repaid the cost of maintaining all the less gifted deaf-mutes of the country.

Thirdly, human nature is so complicated that it is very difficult to say

when a genetic handicap, for instance a metabolic or physical defect, becomes an actual handicap; it may equally well become a stimulation. Both adverse environmental conditions and adverse genetic conditions may 'bring out the best' in some people.

Lastly, according to the statement of the American geneticists quoted above, 'there is little we can do to determine which genes we pass on to our children'. The son or the daughter of a diabetic, be he a genius or a criminal, has probably only half a chance of inheriting the *d* gene. He or she may again be a genius or a criminal, or more probably just an average person. This again will depend on the genetic constitution as well as upon the environment. But the community cannot afford to take the risk of losing a genius, because they may run the risk of getting a diabetic or a criminal.

On the other hand, it should be remembered that medical progress also keeps alive many people who, because of inherited mental or physical defects, are unable to make any contribution to society, and are only a burden. Probably one of the effects of modern medical treatment has been to increase life expectancy of the phenotypes more than life expectancy of the genes. This is due to the fact that most such people are isolated either in hospitals, asylums or prisons, and are thus prevented from having offspring. In some countries, for instance Scandinavia, such people are often sterilized, and can therefore be allowed more freedom.

It should be pointed out in this connexion that sterilization (or isolation) in most cases has very little effect upon the gene frequencies. For most of the mental diseases with which we are concerned show recessive inheritance, often of a very complex pattern, and in all cases the genes concerned are very rare. The vast majority of affected persons are born from phenotypically normal but genetically heterozygous parents (from the combination $Dd + Dd$, in which only a quarter of the offspring will be recessive *dd* children). There are, however, notorious cases of many prolific generations of feeble-minded (a famous quotation is often cited from the ruling of U.S. Supreme Court Justice Oliver Wendell Holmes in a sterilization case: 'Three generations of imbeciles are enough'). Such cases are given a publicity which is hardly justified by their actual quantitative contribution to the total frequency of the genes concerned.

However, the whole discussion of the eventual consequences of preventive medicine on the gene-frequencies and the biological fitness of the human populations is purely academic. There is no going back in human progress. We cannot stop administering drugs or hormones, or discovering new ones, and we cannot give them to the people we like and withold them from those we dislike. This would be an inexcusable violation of the whole ethical foundation of the medical profession. Needless to say, however, all conclusions with regard to the genetical consequences of the progress of medical science are based upon the assumption that we shall be allowed to continue

this progress, and that we can maintain the new ecological niches which are the great achievement of the last few decades of medical research.

There is one more aspect of the medico-genetic problem which should be mentioned briefly, although it is not concerned with gene-frequencies. This is the much more complicated role which heredity plays in longevity. Generally speaking, man's life expectancy is, like everything else, determined both by heredity and environment. This becomes quite obvious from studies of the pattern of ageing in uniovular twins. The reason why man's life expectancy has increased in the last decades is mainly that many of the environmental factors which cause people to die have been eliminated. It is obvious therefore that when the environmental factors which cause death become less important the genetic factors become predominant. Even the barest outlines of the very intricate problems of the genetics of longevity have as yet hardly been touched upon, and the time is long overdue when gerontologists should invite geneticists to participate in their studies. One of the complicated genetic aspects of the problem is of course—as already pointed out by Haldane—that there is no direct selection in the Darwinian sense for or against genes that manifest themselves after the end of the reproductive age. These problems are only mentioned here because increased life expectancy has become a problem of major concern to the welfare state —and its economic effects are undoubtedly much more serious than those of an eventual increase in the frequency of some human genes.

Progress in medical science has created an increasing number of new ecological niches in which genetically handicapped phenotypes may survive. As a consequence of this, certain human genes are undoubtedly increasing in frequency. Although this has been achieved at not inconsiderable cost to the community, we cannot say that it has resulted in a loss of fitness—under the living conditions provided by modern civilization. The main effect has been to increase human variation (polymorphism), and this trend is likely to continue. It cannot be stopped—unless the civilization which has created it comes to an end—and there is no reason for wanting it to stop. This, however, does not mean that we should want to increase the frequencies of undesirable genes. On the contrary, we certainly want to keep them down to a minimum because, both for their own sake and for the sake of the community, we prefer to have our outstanding men as well as our average men —or our criminals for that matter—without diabetes, pernicious anaemia, etc. But with regard to the medico-genetic aspect of this problem, there is not much we can do. The problem is different when we come to deal with gene-frequencies and ionizing radiation.

RADIOACTIVITY AND GENE-FREQUENCIES

There is no doubt that a growing proportion of the world's population has been exposed to an increasing amount of ionizing radiation over the last fifty years, and there is hardly any doubt that this will continue. Since ionizing radiation induces mutations, there is a danger that the mutation rate of human genes will increase and perhaps affect the genetic structure of the human race. However, it is very difficult to form an unbiased estimate as to the extent of this menace of radiation. In attempting to form such an estimate, we must first summarize the fundamentals of radiation genetics.

1. All types of ionizing radiation induce mutations, for instance X-rays, alpha, beta and gamma rays, cosmic rays, neutrons, etc., whether they are produced by X-ray apparatus, radium isotopes, or by atomic detonations. The cosmic rays and the normal deposits of radioactive elements form the background of natural radiation to which man has always been exposed. This background may be responsible for at least a part of our spontaneous mutations—what part, will be discussed later. Mutations are also induced by thermal agitation, by non-ionizing radiation like ultraviolet light, and by many chemical compounds.
2. The ionizing radiation must reach the reproductive organs—in man, the testes or the ovaries—in order to induce germinal mutations which are passed on to the descendants.
3. There is no lower limit for the mutagenic effect of radiation. Even the lowest dose of the lowest energy induces mutations. The mutation rate rises —within a very wide range—in proportion to the radiation dose. Radiation is measured in roentgen units (r units).
4. The radiation dose may be fractionated. It is the cumulative amount of r units given over the whole sexual life of the individual which determines the mutation rate. The result is the same whether 100 r are given within a minute, or whether 5 r are given each year over a period of twenty years.
5. The damage to the genetic material caused by radiation cannot be repaired. There is no going back in heredity. Mutations once induced will be passed on to the descendants until they are eliminated by natural selection.

The last three points are of fundamental importance for evaluating the genetic menace of radiation, because the curve which shows the effect of radiation upon the genes is quite different from the curve which shows the effect of radiation upon the individual.

(a) There is a lower limit to the amount of radiation which causes damage to the individual, so that people may be exposed to a low dosage of radiation over many years without suffering from any of the symptoms of radiation disease.

(b) The organism can repair the injuries caused by even a considerable dose of radiation.

(c) There is no cumulative effect from repeated exposures. The 'permissible dose' to which people who work with ionizing radiation may be exposed with personal impunity is approximately 0.3 r per week.

6. Radiation-induced mutations are qualitatively the same as the spontaneous ones; they are therefore, as a rule, harmful to the individual and to the population. We shall consider this in greater detail later.
7. Certain chemical substances may give protection against the genetic effects of radiation—at least to some extent. Such substances are called anti-mutagens. We do not yet know to what extent such anti-mutagens will be of practical use in protecting man's gonads from the mutagenic effects of radiation.
8. Certain chemicals are known to protect the individual against the non-genetic radiation damage. But at least some of these have proved ineffective as anti-mutagens.

This is a mainly qualitative summary of the facts of radiation genetics. In order to form an estimate of the genetic menace of radiation, we must have much more precise quantitative information. Unfortunately, to obtain this we are forced to draw heavily upon data from experiments with the fruit fly *Drosophila,* with Indian corn, and from radiation experiments with mice. The figures which we should like to know are the following: (a) the spontaneous mutation rate per gene per generation; (b) the total mutation rate per gamete per generation; (c) the number of mutations 1 r induces per gene per generation; (d) the number of r it takes to double the spontaneous mutation rate (this dose is chosen quite arbitrarily as a starting point for the discussion).

We have rather precise information about most of these points for *Drosophila.* We have some information about point (a) in man. We have recently obtained very interesting information about point (c) in mice. From experiments with approximately 100,000 mice, Dr. Russell, from the Oak Ridge Laboratory in the U.S.A., made the rather unpleasant discovery that the genes of mice are about ten times more sensitive to X-rays than the genes of *Drosophila.* Unfortunately (or perhaps fortunately) we do not know anything about point (c) in man—the sensitivity of human genes to radiation. However, by extrapolation from flies and mice to man, we may reach some estimate of the dose required for doubling the spontaneous mutation rate in man. These data are summarized in the table below.

One factor which will affect the calculation is our estimate of the spontaneous mutation frequency in man. Empirical data have been obtained only for very few genes, and such calculations involve a number of uncertainties. The estimates give a rate of 2 to 3 $\times$ 10^{-5}. However, it would not be correct to use these data as average figures, because only those genes which have a fairly high spontaneous mutation rate have been studied. The spontaneous mutation rates of many human genes may be much lower, perhaps of the order of 1 $\times$ 10^{-7} or even less. Hence we are probably on the safe side if we

	Fruit fly (Drosophila)	*Mice*	*Man*
Mutations per gene per generation (empirical data)	1×10^{-5}*	1×10^{-5}***	2 to 3×10^{-5}
Mutations per gamete per generation	1 : 5 to 1 : 20*	(?)	3 : 10 (Muller)* 1 : 1 (Neel)**
Mutations per gene per r unit ('induced rate')	3×10^{-8}*	2 to 3×10^{-7}***	(?)
r doses per generation required to double the spontaneous mutation rate	30 to 50 r	50 r(?)	3 r (Neel, lowest estimate) 80 r (Muller) 150 r (Neel, highest estimate)

* H. J. Muller, 'The Manner of Dependence of the "Permissible Dose" of Radiation on the Amount of Genetic Damage', *Acta Radiologica*, 41, 5, 1954.
** J. V. Neel and W. J. Shull, *Human Heredity*, University of Chicago Press, 1954.
*** W. L. Russell, 'X-ray induced Mutations in Mice', *Symp. Quant. Biol.*, 16, 327, 1952, Cold Spring Harbor.

assume the average spontaneous mutation rate of the human genes to be of the order of 1×10^{-6}.

Let us now see how the different estimates of the dose for doubling are obtained. If we assume that the spontaneous mutation rate in man is 1×10^{-6}, and the induced rate is 3×10^{-7} (corresponding to the highest estimate of the sensitivity of the genes of mice, based on Russell's data), then the doubling dose may well be as low as 3 to 4 r per generation. If, on the other hand, we assume that the average spontaneous mutation rate of the human genes is as high as 3×10^{-5}, and that the sensitivity to radiation is 2×10^{-7} (the lowest value from Russell's data), then the doubling dose may be as high as 150 r. If, however, human chromosomes are more sensitive to radiation than those of mice, we may still have a low doubling dose combined with a high spontaneous mutation rate. There are some reasons for assuming that we are more sensitive to radiation than mice, because the dose of X-rays which induces temporary sterility in man is much lower than the corresponding dose for mice, which is again almost 10 times lower than the sterility dose for *Drosophila*.

Muller has recently calculated that the doubling dose in man is probably something like 80 r. This is based upon the assumption that the average spontaneous mutation frequency in man is approximately 2×10^{-5} (1 in 50,000 gametes), and that the sensitivity to radiation is 2.6×10^{-7} (corresponding to Russell's average figure).

It should be added that Muller assumes that the total mutation rate in man (mutations per gamete per generation) is approximately 3 : 10, whereas Neel

and Shull are inclined to think it may be as high as 1 : 1, i.e. that each gamete contains at least one new mutation. If Muller is right, then a doubling of the spontaneous mutation rate would mean that 6 out of 10 gametes contained a newly arisen mutation—and since each individual (zygote) arises through fusion of two gametes, this would mean that among 10 zygotes there would be 12 new mutations (1.2 per zygote). If we use Neel's estimate, each gamete would contain two new mutations; and each zygote, four.

However, both figures may be far too high. It is only possible to arrive at a trustworthy estimate if we know the total number of genes in human chromosomes, and our methods for making such an estimate are—to put it mildly—very crude. In *Drosophila* there is good evidence that the number of genes is not lower than 5,000, and probably not higher than 10,000. Muller assumes that man has approximately 10,000 genes, whereas Neel's calculation is based on a figure of 40,000. Whatever the true figure, we must indeed agree with the following quotation from a recent textbook on human genetics:

> Even if the estimate is unduly high by a factor of two or even four, this frequency literally brings mutation into the life of each of us. It is no longer a rare phenomenon but a relatively common biological event.[1]

It should be pointed out that there is perhaps further support for the assumption that the doubling dose in man may be as low as 3 to 6 r per generation. Undoubtedly cosmic radiation and other natural sources of radiation are responsible for some of the spontaneous mutations in all species. In *Drosophila,* which has a life span of only a few weeks, it can easily be calculated that natural radiation can be responsible for only a small fraction of the spontaneous mutations, probably not more than 0.02 per cent. The rest of the spontaneous mutations in *Drosophila* must be due to thermal agitation and to chemical mutagens. However, the life span of man is much longer: 250 generations of fruit flies correspond to one human generation. Therefore our gonads are exposed to a much higher cumulative dose of spontaneous radiation. At the same time man is a warmblooded animal, and also his internal chemical environment is probably much more stable than that of the fruit fly. It is therefore not unlikely that thermal agitation and chemical mutagens play a far lesser role in the induction of spontaneous mutations in man than in *Drosophila,* and that most of our spontaneous mutations are induced by natural radiation. This possibility was already pointed out by Haldane many years ago. The amount of natural radiation varies over the surface of the earth, and it is of course higher at high altitudes than at low altitudes. The average cosmic radiation amounts to approximately 0.12 to 0.23 r per year. Assuming that the sexual generation of man is 25 years, we are exposed to

1. Neel and Shull, op. cit., p. 147.

3 to 7 r per generation. This is a figure which is surprisingly close to the lowest estimate for the doubling dose based on quite different calculations. If, however, the doubling dose in man is 80 r, as Muller thinks, then natural radiation can only be responsible for 5 per cent of the spontaneous mutations, and if we take Neel's and Shull's highest estimate of a doubling dose of 150 r, then natural radiation will be responsible for only 2.5 per cent of the spontaneous mutations.

It has been necessary to go over these calculations in some detail in view of the problems which we now face. The calculations are full of loopholes of course and it is not very satisfactory to continue a discussion on the basis of figures which may well vary between such wide limits as 3 r and 150 r. However, as will have appeared from the above remarks, we do not think that those who deny the possibility of as low a doubling dose as 3 to 6 r per generation have too strong a case.

We must now discuss again in some detail the consequence of an eventual increase in the spontaneous mutation rate, on the assumption that we are being exposed to an increasing amount of ionizing radiation.

In order to evaluate this situation we must recall the following three statements: (a) the induced mutations are qualitatively of the same types as the spontaneous ones; (b) mutations are almost always harmful; (c) the fate of the mutations in the population depends upon the evolutionary dynamics of the population, and especially upon selection pressure.

It is probably the experience of most geneticists that it is always difficult to explain point (b) to those who are not familiar with point (c)—the genetic theory of evolution. It is a well known fact that X-rays have been used with considerable success to induce mutations for higher yield in some agricultural plants, especially barley, and that the same method has been used with great success to increase the yield of penicillin in the mould *Penicillium*. It is quite true that when the evolution of such species is guided by man to meet his very special requirements, induced mutations may survive and be successful in the very artificial environments which man creates in his well kept corn fields, or in the penicillin plants. In the above cases thousands of grains of barley or millions of *Penicillium* spores are subjected to a very high dose of X-rays. Only a small fraction survives this treatment, and among the survivors perhaps one out of a thousand mutations is an improvement—with respect to the single character for which we select. All the rest are ruthlessly thrown out. Even the one which may have a positive value in our artificial environment is probably inferior to the wild species in all other respects and would never survive in nature. Obviously such an unscrupulous selection pressure would never be tolerated in human populations, and we can do nothing wiser than try to keep the mutation frequency of the human genes down to the lowest possible level—the spontaneous rate—which has served well enough to bring human evolution up to its present stage.

In order to form a more specific estimate of the mutation pattern in man we must again go back to the evidence obtained from *Drosophila.* Professor Muller has shown that among 1,000 fruit flies whose parents were exposed to an X-rays dose of 150 r, 844 showed no mutations, whereas 156 (15.6 per cent) showed different types of mutations, which can be classified in the following groups:

1. Of these mutations 25 were so-called dominant lethals, i.e. they contained a gene (*DL*) which, even in the heterozygote state (*DL/dl*), kills the individual. Such mutations would therefore cause partial sterility. It may be added that the proportion of this type of mutation is higher in mice than in *Drosophila,* and that there is reason to assume that it would be even higher in man. Partial sterility is therefore one of the most common effects of X-rays.
2. Another 25 mutations were so-called recessive lethals. The heterozygote *RL/rl* was normal and viable, although its fitness was probably reduced. However, the homozygote *rl/rl* was inviable. This is not a desirable type of mutation. The *rl* gene would be passed on to the descendants, until some day a sperm carrying *rl* would fertilize an egg cell likewise carrying *rl.* The resulting *rl/rl* zygote would be inviable. Hence these 'recessive lethals' would be responsible for the 'genetic death' of a number of individuals in some future generations.
3. Among the 156 mutations, 100 were what Muller called detrimental mutations. These mutations have no visible effect, but probably on account of slight physiological changes, individuals carrying them are less fitted to the environment than the 'wild type'. Muller has depicted them as fruit flies wearing umbrellas and galoshes, and they certainly do look very unhappy. This is probably the type about which we should be most concerned in human populations. They are the ones whose fitness may be restored by means of drugs, hormones, antibiotics, etc. As we have seen, their number is already increasing, and we do not want to have more of them than we already get from spontaneous mutations.
4. A very small fraction, 5 out of the 156, were so-called visible, recessive mutants, i.e. mutations in which the heterozygote *Rr* was morphologically indistinguishable from *RR,* but in which *rr* flies showed some visible abnormal characters. In man the albino gene and several genes for mental disorders are examples of this type. If the concentration of such genes increases, the homozygotes (*rr*) will of course also become more frequent.
5. Finally, one out of the 156 mutations was a dominant, visible mutation, one in which the heterozygote *Dd* was morphologically different from the wild type. In man, so-called accondroplastic dwarfism is inherited in that way.

We may use these data as an illustration of the qualitative mutation pattern in man. Certainly none of these mutations can be considered useful or

desirable for human populations, except perhaps in the very long run. We can quite agree with the following quotation from Professor Mather's previously quoted article:

> There can certainly be nothing but genetic disadvantage for man in artificially raising his mutation rate, by irradiation or any other means, above that which has sufficed for his evolution up to the present. . . . We must expect all the distressing hereditary conditions known in man to be increased in frequency by irradiation which reaches the reproductive organs. And in so far as the genetic effects of the radiation are cumulative, even the smallest doses applied at the lowest intensities will add their quota to such suffering and distress. The genetic effects may be long delayed: it may be hundreds of years before a recessive mutation makes itself visible phenotypically. Yet sooner or later the effects of even recessive mutations will be seen, for there is no going back in heredity. A mutation once produced cannot be undone: genetic murder will out. The fact that it may out only after many generations is no excuse for condoning it now.

However, this is only half of the story. The genetic structure of human populations is not determined by the mutation pressure alone, but ultimately by the selection pressure. Therefore the effect of increased mutation rates of human genes will ultimately be determined by the forces of natural selection. This is a most difficult problem to evaluate, because the forces of natural selection probably act differently in different human populations, depending upon their social, ethical, economic and political structure. If there is a balance between mutation pressure and selection pressure, the population is in equilibrium, i.e. the genetic load will be kept down to its natural level, even if the mutation rates of the human genes increase. The biological fitness of such populations is therefore determined only by the mutation pressure, as Haldane showed some years ago. However, as also pointed out by Haldane, if the mutation pressure is increased by a factor of u, then approximately $2u$ gametes must be eliminated in order to restore equilibrium. The price which must be paid by human populations to restore equilibrium is primarily paid by those who carry the genetic load, and by their closest relatives—and it may well be a terrible price.

If human populations are not in equilibrium—and some evidence has already been given for assuming that the genetic structure is changing in the highly civilized welfare states—the situation may be slightly different. An increased mutation pressure may here for a time increase the genetic load of mutations. The primary effect of this will be felt by the community at the economic level, since the number of totally or partially unfit people will increase. This means more hormones, vitamins and drugs, more doctors and nurses, more hospital beds and asylums—and more frustrated lives. In this connexion it may perhaps be pointed out that many of the modern welfare states, and especially the small ones, have a very small economic margin of safety. Obviously a state consisting only of doctors, nurses and patients is inviable. It will be the economic resources and the economic margin of safety which will decide how high a percentage of the country's national

budget can be spent on social and medical security without seriously affecting general progress. Muller thinks that a doubling of the spontaneous mutation rate in man would be a catastrophe, but he thinks that a 10 per cent increase may be tolerated. However, the answer to this problem will depend upon the country's economic resources. It may be that the state will have to make a most unpleasant choice between sacrificing some of the ethical principles of which it is rightly proud, or suffering an intolerable economic burden. But in the long run—the very long run—the choice rests with nature, because ultimately natural selection always wins, and a proper balance between mutation pressure and selection will be restored. However, the price for restoring genetic equilibrium will again be paid at the family level, and it may well be an even more terrible price than in the more primitive communities.

THE DANGERS OF RADIATION

We have stated the case for genetics, and we must now turn to another issue: is there any reason to believe that human populations in the last decades have been, and in the coming decades will be, subjected to an increasing amount of ionizing radiation? The answer to this question can only be given by the physicists and radiologists, and the geneticist can only point to a number of obvious facts. Undoubtedly man's daily life is becoming more and more 'radioactive', but fortunately only a small fraction of this radioactivity is likely to reach the gonads.

Already for many years a very small fraction of the population—the radiologists—has been subjected to a yearly dose of radiation which from a genetic point of view is not inconsiderable. However, this is such a small fraction of the total human population that it is very unlikely to affect its genetic structure. Obviously the patients submitted to X-ray examinations and X-ray therapy are often subjected to a rather heavy dose of radiation, but here of course the good far outweighs the evil—with a few notorious exceptions. Muller has pointed out a flagrant example of misuse of X-ray apparatus: the practice of inducing temporary sterility in young men by giving them a heavy dose of X-rays on the testes.

A probably much more serious problem arises from the fact that 'radioactivity' has lately almost become a fashion. Already self-illuminating watches raise a problem, more perhaps for those who make them than for those who wear them; but sooner or later the watches are thrown away more or less carelessly, and then this radioactivity passes out of our control. The pilots who fly the modern aeroplane are subjected to a rather heavy dose (very close to the permissible dose) from the self-illuminating control-instruments, and again this applies to the workers who make these instruments. However,

these are useful and even indispensable applications of radioactivity. Much worse are radioactive toys now manufactured on a large scale for small children, and the sooner such toys are prohibited the better. Also one of the latest creations of modern civilization, self-illuminating toilet seats in rest rooms, are certainly not inventions which appeal to geneticists.

The soft X-rays emitted from television screens cause great concern among radiologists, because we are here probably for the first time dealing with ionizing radiation to which very large groups of people, and especially children, are subjected for long periods. It is, however, doubtful whether such rays will penetrate the gonads.

To these already serious quantities of radiation is now added the radioactivity introduced by the atomic age. A very large and growing number of scientists is working with radioactive isotopes provided by nuclear reactors, and like the pioneer X-ray physicians, they are not always handling their tools with proper consideration for their own safety, let alone that of their genes and chromosomes. A very serious problem arises with the application of isotopes in industry. Radioactive material is now being handled by an increasing number of skilled and unskilled workers. Very considerable safety measures have already been taken to protect the safety of such workers (with the exception of miners in uranium-mines where—as pointed out by Professor Kathleen Lonsdale—an unpardonable negligence seems to prevail). However, in most cases protection is considered sufficient when radiation is below the dose which may damage the soma. But from a genetic point of view this is not enough. It is necessary to bring the exposure down to the lowest possible level in order to protect the chromosomes, and especial protection is needed for the gonads. This may cost more money, but such an investment would be repaid many times over in future generations.

Indeed, the problem of protecting the world population against radioactivity in the atomic age is a tremendous one, even if we confine ourselves solely to the peaceful aspects of atomic energy. It is not suprising that the World Health Organization has recently given highest priority to this problem. One can only hope that it will give its utmost consideration to the genetic aspect of the problem, and will concern itself with protecting not only the soma but also the genes.

But there are also the military aspects of atomic energy. Again, only the physicists and only those who have access to top secret, classified information may be able to evaluate this problem. It is, however, a fact that the hydrogen bombs which were exploded in 1954 (probably two in the Pacific and two in Siberia) resulted in an increase in radioactivity measurable in most parts of the Northern Hemisphere, and especially in Japan, where the rainwater became so radioactive that for a time it was undrinkable in certain regions. The firms which make photographic films have also their tale of woe to tell, as some of their stocks were damaged by radioactivity. In Denmark the radio-

activity of rainwater (which is not used directly as drinking water) was increased by a factor of 2 to 3 and came close to the permissible dose. We do not know how much of this radiation may ultimately reach man's gonads. He may get it directly from the vegetables which he eats, or he may get it indirectly from the meat of the animals that had drunk the radioactive water and eaten the radioactive vegetables. Some of the radioactive isotopes may be concentrated in the body so close to the gonads that the radiation may affect the chromosomes; others, for instance radioactive carbon (which incidentally has a half-life of 5,000 years) or radioactive phosphorus, may be incorporated directly into the genes (in desoxyribonucleic acid and the protein of the chromosomes), and when the isotope distintegrates it may destroy or change the gene. The problem of the concentration of isotopes in the course of the metabolic turnover is undoubtedly one about which we should be most deeply concerned.

Even if the geneticist had the necessary physical data, he could not estimate how much genetic damage had already been done, because he does not know how sensitive the human genes are to irradiation. Perhaps the most distressing aspect of the problem is that we do not know enough to form a sound evaluation of the damage, but that we do know enough to be deeply concerned about the problem. Hitherto geneticists have felt rather comfortable about the old prophecy that the sins of the fathers should be visited upon the children unto the third and fourth generation, because they knew that the acquired characters were not inherited in the old Lamarckian sense. But, on the threshold of the atomic age, they are no longer so sure.

As for the possible effects of an atomic war, the British geneticist, Professor G. Pontecorvo of Glasgow University, recently pointed out that 'If mankind cannot avoid such a war, there is not much point in speculating on the genetic consequences'.[1] None the less, one point should be emphasized. Modern civilization has increased man's variability by creating new ecological niches. Many such niches, the 'insulin niche', the 'antibiotics niche', etc., would unavoidably be destroyed during an atomic war, at least temporarily. The most civilized states, those with the highest social and medical standards, would in this respect suffer much more seriously than the more primitive states.

CONCLUSION

What then is man's responsibility to his genetic heritage?

Our first responsibility is to realize that such a problem does exist, and that on no account must it be ignored. It is a main thesis of this article that

1. See *Nature, 174,* 960, 1954.

human progress is determined not only by economic, political, and ethical forces, but also by the laws of biology. Genetics, because of its bearing on evolution mechanics, holds the key to most of the biological problems with which our political leaders and economic planners should be concerned. It is therefore vital that the fundamental principles of genetics, and of what has here been called 'gene ethics', should be made familiar to as many people as possible. The teaching of genetics and evolution at all levels of our educational systems should be given a very high priority.

Our second responsibility is to continue to create the best possible environments for the human genotypes, whether we think that their present contribution to the community is valuable or not. Obviously this trend should not be stopped, and it cannot be stopped unless human progress stops.

Our third responsibility is to pass on to our descendants, without injury, the genes and chromosomes which we received from our ancestors. We should treat them not as our own property but as the property of our species and of our descendants. This means that we should avoid all unnecessary irradiation of our genes and chromosomes. We can do little to decrease our load of spontaneous mutations, but we can do much to prevent the mutation rates of our genes from increasing. The utmost care should be taken to protect those who are handling X-rays, isotopes, etc. 'Radioactivity' should be treated seriously and never used as a toy. Whenever it is introduced in new fields of research or industry, the gains should be weighed carefully against the possible losses, and genetic considerations should be given their full weight.

We do not want the age of science to be based upon incalculable risks. And incalculable they are literally, because we do not know enough about the sensitivity of human genes to ionizing radiation and about the fate of radioactive isotopes in the metabolic processes. It may well be that the possession of hydrogen bombs by all the major powers constitutes at least a temporary guarantee of world peace. But it would be most difficult to convince geneticists that we need to be constantly reminded of the possession of such terrible weapons by ever bigger nuclear test explosions, because this would mean a continued exposure of a large part of the world's population to incalculable genetic risks.

Undoubtedly, science and technology have today created almost unlimited possibilities for further human progress and evolution. Unfortunately, at the same time we have reached a stage where human mistakes can have a more disastrous effect than ever before in our history—because such mistakes may drastically change the course of man's biological evolution.

SOME PROBLEMS IN UNDERDEVELOPED AREAS

by

E. W. GOLDING

Mr. Golding, formerly Senior Lecturer in Electrical Engineering at Nottingham University, is Head of the Rural Electrification and Wind Power Department of the British Electrical Research Association. During the past two years he has visited a number of underdeveloped areas in different parts of the world and studied some of their problems. Readers of Impact *will remember an earlier study of his—on local energy sources for underdeveloped areas (vol. V, no. 1, spring 1954).*

It is not easy to define an underdeveloped area. But without question a large fraction of such areas is made up of the arid zones, which occupy almost one-third of the earth's land surface. In addition, apart from the polar regions themselves, there are vast areas in Greenland, northern Canada and Siberia which are 'cold deserts'. These give way, as one moves a little further south, to wide belts of coniferous forests running across Canada, and from Norway, Sweden and Finland across the U.S.S.R. Then there are the steppes of Russia and the tropical forests of Brazil and central Africa.

It is commonly realized that an enormous area stretching from the Atlantic coast of north Africa right through Egypt and the Middle East to central Russia is desert or semi-desert, but one learns, perhaps with surprise, that something like half of Australia is arid, while only a quarter of the country has enough rain to grow crops. Even the United States, which would never be regarded as an underdeveloped country, has an arid zone of more than one-third of its total area.

Perhaps the best criterion, though admittedly a very imprecise one, is whether a particular area is contributing its share towards the requirements of the rapidly increasing world population. Raw materials, such as solid and liquid fuels, metals and other minerals, wool and cotton, etc., are badly needed. But the greatest need is for food. It has been stated authoritatively that some two-thirds of the world's population have less than a subsistence diet. Food supplies are now even less adequate than they were in the seventeenth century. The population tends to increase in geometrical progression, but food supplies only increase in arithmetical progression. To provide an adequate diet for all, the supply of food should be doubled during the next ten years.

The intention here is to consider the possibilities of making fuller use of

the land areas of the world, leaving aside the seas. We do, of course, exploit the seas and oceans to a limited extent through fishing and whaling and by harvesting seaweeds, but undoubtedly the return from these sources is still very small in relation to the vast total of energy which the waters receive annually in the form of solar radiation.

There is, indeed, a very widespread realization of the need for greatly increased development of agricultural land and of many other natural resources. But, clearly, this cannot be brought about easily; there are difficult problems to be solved, and their nature changes from one country to another. The rapid advances in scientific knowledge can, and must, be applied to the solution of these problems.

THE AIMS AND MEANS OF DEVELOPMENT

Before turning to the difficulties, let us consider briefly the aims of development and the requirements for its successful prosecution.

Firstly, the aim should be to utilize the natural resources (in whatever form they may be) so that, within a reasonable period of time, the area may become self-supporting. It may be capable of supporting a new, or greatly increased, population as far as food is concerned, but this is not an essential requirement. The exploitation of mineral or forest resources may well justify importing food. For example, the driest desert of all—the Atacama in Chile—provides great wealth in the form of nitrates and has the largest copper ore reserves in the world, and in the Rajasthan desert in India there are salt works large enough to supply a good proportion of the salt requirements of the country.

But these are not true instances of developed areas; they are rather developed pockets in areas which are otherwise unproductive. It is probably correct to say that deposits of valuable minerals will generally be exploited as the need for them arises, so that the localities in which they lie can be expected to develop almost automatically. Even so, there are marginal cases where, owing to the present lack of facilities such as transport and power supplies, the cost of exploitation may be about equal to, or even greater than, the value of the product. Here, unless the product suddenly becomes very valuable, development is not likely to take place without some stimulation outside the realm of ordinary commercial enterprise. We have seen this happen in recent years with uranium deposits.

There is, of course, no essential difference, from an economic point of view, between an unexploited mineral deposit and an undeveloped area of land which, given adequate treatment, would be capable of yielding valuable crops. The demand for the product exists in both cases, but the solution of the problem of development is more easily seen in the case of minerals than

in that of food crops. The means to be adopted may be employment of sufficient capital equipment for working the deposit or for transporting the mineral. But given a wide expanse of uncultivated and largely uninhabited land, the method of converting it into a self-supporting area is much more difficult to determine. One is immediately brought up against questions of a very varied and complex nature—questions of climate, of the structure and agricultural potentialities of the soil, of drainage and irrigation, of the characteristics and skill of the inhabitants who will have to cultivate the land, as well as problems of providing capital, equipment and supervision, power supplies, transport, medical services, education and other amenities for an inevitably scattered population.

Often basic data for an undeveloped area are almost completely lacking. No one knows, with any precision, the amount of rainfall in different parts of it, the annual duration of sunshine or of winds (whether potentially useful or detrimental to agriculture). The depths and extent of underground water supplies are uncharted, and the salinity of the water is unknown; extremes of temperature are unrecorded, except at a few easily accessible places; and knowledge of the geological structure is imperfect.

The reason for these deficiencies in basic data is clear enough: there has been no incentive to obtain information for which there was no obvious use. Again, the sparsity of the population has made observation and measurement of climatic phenomena difficult to undertake. At least the main geographical features—the rivers, mountains, forests, plains, and lakes—are commonly known, so that cartographical surveys may not be required; but detailed surveys, with the object of supplying the missing data just mentioned, are certainly needed. Several surveys of this kind, employing teams of scientists —meteorologists, geologists, ecologists, biologists, engineers and hydrographers—have already been made in Australia, Somaliland and other countries. These have been undertaken by national organizations or have been sponsored by Unesco and other United Nations Specialized Agencies.

Certainly no new development of an extensive area for agricultural purposes can proceed effectively without such surveys, which provide the indispensable information for the design of the necessary equipment and the planning of the development scheme. Theoretically, at least, it should be possible to determine, from sufficiently comprehensive data, how many people could maintain themselves on a given area of land to be developed. As might be expected, the density of population in predominantly agricultural areas varies very widely.

In Japan and China, for example, which use centuries old farming methods without the aid of modern equipment and techniques, the density was between two and three thousand per square mile of cultivated land some fifty years ago. On the other hand, in semi-arid areas such as Somaliland, where the people are stockherders and follow a nomadic way of life, the density is

about ten to the square mile; but even this low figure must be relatively high when compared with that for some other areas of North Africa and the Middle East. In practice, any estimate of the population which could be carried by a given area would have to take into account much more than the physical and climatic factors—though these could perhaps be fitted into a formula to provide the required answer. It might be shown that the energy equivalent of the food required to sustain one person—which is about 2,500 to 3,500 calories per day—is supplied by solar radiation (at an average value of, say, 0.1 kw. per square metre) falling on little more than 1 square metre. But to base population estimates on such calculations would be entirely unrealistic, for the solar radiation has to be converted into food by plant and animal agencies of widely varying efficiency. The climate, the nutritive value of the soil, the availability of water, and other factors, play their part in deciding what foods could be produced; but the actual diet of the population in a given area is affected by more complex factors. Long established customs and religious beliefs may be very important. Thus, an area might be well suited to the growing of vines and other fruits and vegetables, but the inhabitants may not be wine drinkers or vegetable eaters; pig-farming might perhaps be profitable, but the local religion may forbid the eating of pork. There are many such difficulties created by incompatibility between agricultural possibilities and local customs and tastes. One way to overcome such difficulties might be through the organization of trade facilities for exchanging foodstuffs. But this solution is not likely to be satisfactory economically; transport charges would be a handicap, and, further, there is not likely to be much enthusiasm for producing crops which are not for local consumption. Nevertheless, instances of such an arrangement could be quoted; for example, villages in the highlands of Ethiopia prosper by exporting locally grown khat (*Catha edulis* FORSK) leaves (containing the drug cathine, which is in high demand in Middle Eastern countries) by a special air service to Aden. Foreign trade of this kind, however, demands organization which would scarcely be practicable in many of the underdeveloped areas. It calls for a money economy, as distinct from a pastoral economy, and for an understanding of commercial methods and responsibilities, which are at present beyond the grasp of the local inhabitants. Until development and education have progressed to a stage where extensive commercial activities are possible, probably the best method would be to introduce, through agricultural advisory services, crops which would be acceptable to the local population. But this may not be easy to accomplish with traditionally conservative agricultural peoples. In this task, leadership and example by the more enlightened among their own community can be the best help.

These comments on methods of development tend to imply that the areas considered are inhabited by primitive peoples whose present methods of cultivation and of exploitation of local resources are insufficient for anything

more than their own bare subsistence. This is not by any means true of all underdeveloped areas; but though no two of them are alike, they all need to improve methods of land utilization. They differ radically in so far as the availability of immediate facilities for development is concerned. Backward areas forming part of a wealthy and industrialized country such as the U.S.A., if they are likely to show an adequate return, could doubtless be improved in a relatively short time by the provision of capital equipment; but the underdeveloped areas of small and much less wealthy countries, e.g. in the Middle East, Asia or South America, may call for both capital and technical assistance to be supplied from outside, perhaps through the medium of international organizations.

COMMON PROBLEMS IN UNDERDEVELOPED AREAS

In spite of the wide differences between the areas which we are considering, there are certain problems which appear to be common to many of them. These problems can conveniently be grouped under three headings: sociological, agricultural, constructional and administrative.

Sociological Problems

One cannot plan the development of an area realistically without considering the probable effects of such development on the existing population or on the population which may materialize as a result. Leaving aside the exploitation of resources such as minerals, which demands the establishment of communities close to the location of the works, we must assume that the population is more or less uniformly distributed over the area so as to take full advantage of its agricultural possibilities. But one of the commonest problems encountered by governments responsible for thinly populated rural areas is that of preventing the drift away from the land towards the towns. In view of the amenities which a town offers, this is a very natural trend, and one which is not easy to counter. But it creates problems, both by the consequent neglect of the rural areas and by the unemployment which it forces on the towns. A town can only prosper if it is an industrial or commercial centre, but for this it must depend upon the mining or agricultural activities of the surrounding countryside; townspeople cannot continue to prosper by 'taking in one another's washing'.

On the other hand, congregation in communities has the advantage that the authorities can carry out educational programmes more easily; it also promotes the growth of political consciousness, which may lead eventually to the inhabitants taking over responsibility for government through their own leaders. Without informed leadership of this kind, development of some of the underdeveloped areas will present an even more difficult problem.

Agricultural Problems

Over much of the desert and semi-desert area in North Africa, Arabia and the Middle East the nomadic way of life is a common feature. The people are stockherders rather than cultivators, and they move about the country with their flocks of goats, sheep and camels, following the herbage, which grows up rapidly when the rain comes to a particular district. Small communities, of a purely temporary nature, arise when the nomads pitch their tents, or erect their portable huts, near to pastures extensive enough to be worth halting at for a time. In some areas there may be clusters of semi-permanent structures, of the mud-and-wattle type, which are inhabited only at intervals.

This way of life, which has continued in some parts of the world for many centuries, certainly breeds a sturdy independence and virility, and it may be that stockherding is a good means of making use of the limited agricultural resources of the area. But the total annual yield from land so used is small; moreover, when the rains fail, stock die in thousands and the inhabitants run the same risk. Improvement of pastures is urgently needed, and this requires the advice of experienced grazing officers, and research to discover the fodder crops best suited to conditions in the area concerned. An example of successful development along these lines comes from Australia, where large areas have been converted from almost useless semi-deserts to valuable grazing by the introduction of subterranean clover (*Trifolium subterraneum*). Incidentally, the value of the scientific approach to problems of this kind was well illustrated in this instance, when it was found that the death of quite large numbers of sheep, grazing on what appeared to be adequate pastures, was due to mineral deficiencies—particularly that of copper—in the soil.

Very often improvement of grazing will involve its strict control for some years until the cumulative process gets well under way. In a country inhabited by primitive peoples education, through patient demonstration and example, will be needed to persuade them to accept such control.

Nomadism, though doubtless a necessity in many dry areas, at least under present conditions, is unsatisfactory as a method of obtaining an adequate return when practised on land which is not infertile. The land can be, and often is, overgrazed, with the result that the vegetation cover is so thin that there is nothing to prevent immediate runoff when rain comes. Floods and soil erosion ensue, and the area continually depreciates. Fortunately, not all of the indigenous shrubs and plants are palatable to stock, so that a few are left uneaten, and these afford at least a little protection for the soil.

The cultivation of grain and fodder crops, such as the various forms of millet, gives a better return from the land where sufficient controlled irrigation can be supplied, but guidance from agricultural officers is badly needed

to ensure that the best use is made of the irrigation water by a proper choice of crops and by the adoption of efficient methods of cultivation.

In some instances contour ploughing can be used, as it was by the Tennessee Valley Authority, to minimize soil erosion, but this is a technique which must be introduced by skilled agricultural staff.

Irrigation, when it can be provided, brings its own problems; the quantity of water to be given for a particular crop must be controlled, and drainage is as important as the irrigation itself. Many agriculturally derelict areas, especially in hot dry climates, have saline soils and waters; if drainage is inadequate, irrigation can accentuate the salinity by raising the water table, so that crops fail from this cause.

In some countries where little government control has been exercised over long periods, land has been cultivated without any proper system of crop rotation or application of fertilizers, until it has become exhausted. The cultivators have then moved on to other plots of ground to begin the process over again. Another way in which land has suffered serious deterioration has been through the creation of dust bowls as a result of indiscriminate felling of timber; excessive clearing of shrubs in an area denuded of windbreaks, leaving nothing to hold the soil, allows the wind to bring about erosion which can be as serious as that caused by water. The clearing of undeveloped land for cultivation should therefore be undertaken with due regard for these factors.

A study of the indigenous vegetation in an area scheduled for development is, for several reasons, a necessity. The character of the vegetation affords the skilled observer useful information as to the suitability of the climate for the more valuable crops, the depth of the water table, the chemical content of the soil, etc. Such a study may also be repaid by the discovery of varieties of trees and plants which may provide raw material for local industries. Detailed information on the occurrence of grasses or other pasture plants, and the influence exerted by the rainfall in this respect, might lead to a plan for preserving crops so as to prevent them from becoming overmature and less nutritious before they are eaten by stock. In the same way, studies of the fauna and insect life of the area indicate the difficulties which may be expected in the shape of pests and diseases of crops.

In areas where primitive agricultural methods are followed, it is important to determine how far these methods are wasteful of man and animal power. The simplicity of the idea of employing animals—bullocks, camels or buffaloes—tends to obscure the fact that their use is uneconomical when the proportion of the yield which they themselves consume is taken into account. Their daily food demands are of the order of 3 lb of dry matter per hundredweight of their own weight, and this corresponds to four or five times as much fodder in the natural, undried state. Their consumption is thus considerable.

Problems of Construction and Organization

Under this heading there are many problems which are common to most underdeveloped areas. Perhaps the greatest is that of building and maintaining roads under the difficult conditions frequently encountered. There are no railways to serve these areas, which often rely on animal transport—camels, mules, donkeys or bullocks. Motor transport is therefore essential if backward areas are to be opened up. At present such transport usually takes the form of utility cars—multi-purpose motor lorries carrying both goods and passengers in a glorious mêlée which is good for neither of the two classes of 'freight'—or primitive forms of omnibus intended mainly for passengers. These vehicles have to be driven over routes which change from day to day according to the weather or the extent to which preceding vehicles have rendered a route impassable by breaking up the surface. Sometimes there are roads which follow more or less the same track, but their surfaces are, in the main, so bad as to be destructive to all but vehicles of the 'jeep' or 'land-rover' type. These roads cross the beds of streams at intervals. There are seldom bridges; the crossings are by fords, which are passable when the water is low but quite impassable at times of spate. Travel is therefore a hazardous business. One may have to 'camp' for hours—even for days—while waiting for the spate to subside sufficiently to allow the river to be crossed. The need for more dependable communication is obvious, but the method to be followed in achieving it is much less so. It is not merely a question of making a surface to carry the traffic over ground which may change rapidly from soft sand to near-swamp, but of maintaining it against the action of climatic extremes. Torrential rains may alternate with periods of very hot sunshine. Uncontrolled flood water may wash away whole stretches of road. In some areas severe winter may bring other difficulties in road maintenance. Is it possible to devise road surfaces which can be made—or perhaps prefabricated and laid—economically and with little need for skilled maintenance? Again, if the area, when developed, is to have any significant amount of external trade, routes must be studied, and port facilities provided if there is a sea coast.

Internal trade is important if the inhabitants are to adopt a money economy, as distinct from a pastoral or barter system whereby stock and agricultural produce figure as units of exchange. Banks, shops and other facilities will therefore be needed in country centres.

Because of its erosive effects, flood water needs to be controlled without delay in dry areas and in the tropics. In fact, in arid and semi-arid areas it is hard to know whether the lack of rain or the excess of rain does the most damage. Often there is no 'happy mean'. Either there is no water or there is too much of it. Apart from the erosion and destruction which floods cause, another drawback for the cultivator is that he cannot rely on the water taking

the same course in successive floods. His fields, well watered in one season, may be left 'high and dry' in the next because the capricious river has taken a new course. There appears to be some prospect of control by the construction of waterworks on, or immediately below, the high ground where the rain usually falls, and canalization of the flow towards the lower areas. This can form the basis for an irrigation system, which should incorporate 'drops' or locks with sluices so that the water can be diverted to the adjacent lands. The planning of such systems is not, however, a simple matter; the irrigation canals must not be too deep—or the water cannot easily be conveyed, without pumping, to the irrigated land—nor must they be too steeply graded—or they will be eroded. The channel beds should be as impermeable as possible, so as to minimize water losses, and the canals must be kept free from vegetational growth, which may impede the flow of water.

Good supplies of drinking water are essential. Although it is certainly remarkable how bad the drinking water of a community can be without producing any apparent ill effects on the people, such a situation cannot be accepted as satisfactory. Constant use of contaminated water no doubt renders the population immune to diseases which would attack a newcomer, but it is nevertheless to be avoided. There is thus need for surveys of underground water reserves, experimental well-boring and the introduction of mechanical pumping.

Medical and veterinary services for the inhabitants of thinly populated areas are not easy to organize, though small hospitals or clinics can be established at country centres. These can be staffed to a certain extent by members of the local community who have been given a period of training sufficient to enable them to deal with minor ailments.

Education is difficult to organize when so many of the peoples concerned are illiterate. Indeed, they may have no writing system so that one is immediately faced with the need to teach a second, written language in order that the pupils may read. Until a much greater proportion of the populations concerned can read—the present literacy rate is often 1 to 2 per cent—the only effective means of disseminating information quickly over wide areas may be through radio broadcasts in the spoken language. This method has, in fact, been used with some success.

While more general education may be a long process calling for much patience and understanding, specialized knowledge such as that required for the improvement of agriculture is easier to impart. It is often possible to show, by demonstration schemes or by direct advice from agricultural officers, what results can be achieved by the use of new methods. Primitive cultivators are not slow to appreciate an increased yield from the same piece of land if this can be obtained without any significant capital outlay and by the adoption of a technique which they can understand. The organization of agricultural shows at which competitions are held with prizes for crops, animals and

agricultural skills (such as ploughing) are helpful in encouraging improvements.

Nor is it always difficult to impart knowledge of simple engineering or technical matters. Local populations often show considerable mechanical aptitude; they have their own forms of craftsmanship, which may be very advanced, in fashioning domestic utensils, furnishing and implements; and this aptitude can be exploited through instruction in technical classes or by direct advice.

Bad housing is another serious trouble in many backward areas. Through the lack of capital and suitable building materials, people are forced to use local materials—mud bricks, timber, wattle or leaves—which, unless skilfully employed, make poor houses. Again, such peoples know little about hygiene, and sewage disposal is seldom considered. In view of the need to use local resources rather than to import materials, there is scope for research —and subsequent advice to the inhabitants—on the possibilities of improving the technique of using local resources. It is by no means certain, for example, that a mud-brick house must necessarily be unsatisfactory. Building research, in general, plays an even more important role in underdeveloped countries than in industrialized countries.

TECHNICAL ASSISTANCE AND THE EXCHANGE OF INFORMATION

During the last decade technical assistance to backward areas has been provided on a considerable scale through the United Nations and other international agencies. Although much remains to be done, it is safe to say that no country need continue to suffer from underdevelopment through lack of expert technical advice (which is often accompanied by the provision of basic equipment). But perhaps even more important than the provision of temporary help from outside experts is the training of the local people to carry out the work on the lines suggested to them. In many instances it is impossible for experts, who often occupy important positions in their own countries, to spend long periods away from their own work. Moreover, there are at present too few experts available for undertaking development of this kind. It is not a question of remuneration, but rather one of the persistent shortage of suitably trained and experienced persons. It is difficult to remedy this state of affairs, because the need is for men with long and varied experience in a particular subject, not merely with technical training. Herein lies a danger to the operation of technical assistance schemes.

Perhaps the best solution to the problem of ensuring progress subsequent to the initiation of a development scheme would be to increase the number of fellowships or studentships given to young men from the countries concerned. If the appropriate expert cannot be spared from his normal duties

for a long period, there is no reason why trainees should not spend some time in his laboratories or at research stations where they can acquire sufficient knowledge to run the scheme in their own country with occasional guidance from the expert.

The exchange of information between representatives of the underdeveloped countries and those of the more advanced ones at international meetings cannot fail to be helpful. Thus, for example, the annual symposia organized by the Unesco Advisory Committee on Arid Zone Research, held in a different area each year, afford an opportunity to those responsible for development in underdeveloped areas to put forward their views and explain their problems to experts from countries experienced in the matter, and receive advice. There are, in a sense, two sides at the conference—the teachers and the would-be students—and each can learn from the other. And, incidentally, there is no better way of bringing about international understanding and good fellowship than by meetings of this kind. But conferences can only be a beginning; the test of their worth lies in their results. They appear to provide an excellent forum where agreement could be reached on development schemes for international sponsorship, with arrangements for subsequent exchanges of information on the progress of the schemes and for demonstration visits. These remarks apply not only to the development of arid zones; similar meetings concerned with the development of tropical areas, or even temperate ones, could serve the same purpose.

PROBLEMS AND DEVELOPMENT PLANS IN DIFFERENT COUNTRIES

Having outlined some of the difficulties which hamper progress in the underdeveloped areas, the writer will now review some successful developments which are already under way and of which he has first-hand knowledge.

The Aden Protectorate

The Aden Protectorate, which has an area of 112,000 square miles—slightly greater than that of the British Isles—consists of a strip of land with a 740 mile seabord along the Gulf of Aden, and the Port of Aden as its main commercial and administrative centre. It is bounded on the north by the Yemen and Saudi Arabia, and is undoubtedly an arid or semi-arid area. The eastern part is mainly desert or barren hill country. Towards the west, inland, there are mountains rising to some 8,000 feet where rain gives rise to a number of rivers and streams which flow spasmodically but, when in flood, bring down large quantities of water—and much silt—to the lower lying plains, which are almost rainless. The agricultural history of the western part of the protectorate during the last few centuries has been somewhat similar

to that of the ancient Babylonian empire, under which agriculture flourished until wars and conquests brought about the destruction of the efficient irrigation systems. In the case of Aden, it was the persistent feuds between local tribes which caused neglect of irrigation, with consequent deterioration of agriculture almost to the point of extinction.

But the need for food during the last war helped to heal the feud between the two main tribes in the Fadhli and Yafa'i states, situated in the potentially fertile area of the Abyan delta watered by the Bana and Hassan rivers. In 1943 the Aden Government entered the Abyan area and, with the consent of the two states, started a four-year development scheme with funds supplied by the Colony of Aden. The success of the scheme led to the formation of the Abyan Board in 1947.

The purpose of this Board, which has a British chairman and managing director and includes two representatives from each of the two states, is to maintain and improve the irrigation of the Abyan delta, and to develop eventually some 100,000 acres, thus bringing under cultivation land which had previously produced a negligible amount of food.

The Board is a good example of an organization designed to promote collaboration between local landowners and a semi-destitute population in the interests of prosperity. It started with loans of some £270,000 ($750,000) from the British Government's Colonial Development and Welfare Fund. Much of this sum was devoted to improving the functioning of the irrigation canals by clearing their beds, adding 'drops' or locks, and building sluices and off-shooting channels. The Board does not itself own land, but provides the water, decides which crops the tenant farmers shall grow each year, and advises them on methods of cultivation. In return for its services it receives 25 per cent of the value of the main crop—long staple cotton which it buys from the farmers and markets after processing—and charges £2 ($5.60) per acre for the water supplied for other crops. These are mainly sorghum and bullrush millet, which provide grain for the population and fodder for their animals. About 60,000 acres—more than half of the total area—has already been developed under the Board's scheme which is now self-supporting. As early as 1951 the cotton sold totalled 9,890 bales (valued at £867,000 or some $2,400,000) but by 1954 the area under cotton had reached 20,000 acres (its probable maximum) with a production of some 20,000 bales. The income from cotton is the foundation for further development of the area; but food crops must also be grown, and the approximate ratio of the areas under cotton and grain will be 1 : 2. Although some tractors and earth-moving equipment are used by the Board, most of the farmers, as well as the Board, use bullocks for field cultivation and for making the 'bunds'—the water-retaining banks of earth round the fields. Camels are used for transport.

A significant feature of the Abyan scheme is the aptitude of the population

for farming of the type required. In the Yemen the population was used to the technique of bund making, so that the influx of this population to the Abyan area (there are now 5,000 people in the settlement of Giar—the headquarters of the Board—where only a few brushwood huts existed ten years ago) has provided the labour essential for success. Incidentally, the Arab workmen are also skilled in the building of stonework, which is fortunate for the irrigation engineers. At present the Board is concentrating upon the restoration and improvement of the old-established system of irrigation, which was in a derelict state; later, when progress makes it economically possible, new canals and reservoirs can be built.

Naturally there are many problems to be faced—agricultural and scientific as well as social and administrative. One of them is that of preventing disease in an area where the same crops must be grown continuously; another concerns crop rotation to maintain fertility. Then the water table rises to a high level on flat irrigated land where drainage is not adequate, and this may put land out of cultivation through the concentration of mineral salts thus caused. Again, each year perhaps a quarter of the land must be left fallow, and this raises the problem of how to compensate the farmers concerned. Some parts of the area are capable of bearing other crops—vegetables, fruits and leguminous fodder crops—and it is necessary to experiment in order to determine which of these will serve the purpose best.

The water in many of the wells is saline, and new sources must be found by boring tube wells. When these have been successfully established, power must be provided for water pumping. In view of the high transport costs of imported oil fuel—not to mention the difficulty of maintaining oil engines under such conditions—the possibilities of using wind power for pumping are being considered. The area appears to be windy, and this source of power might be applied successfully—as it has been for many years at the salt works in Aden itself, where a dozen or more windmills are used for pumping brine. To pump water at the rate of 1 cubic foot per second from a depth of 50 feet (which is probably a reasonable estimate of the depth in the protectorate) one needs about 12 h.p. Wind measurements have yet to be taken, but an economically designed wind pump would probably function annually for about 2,000 to 3,000 hours (some 30 per cent of the year).

The progress made in the Abyan has not been achieved without much hard work, patience and wise organization, but the transition from barren sand dunes to cultivated fields is so impressive that it is a most encouraging example.

The Somaliland Protectorate

This territory, which has been a British protectorate since 1887, forms part of the 'Horn of Africa'. It has a seaboard some 450 miles along the southern

side of the Gulf of Aden, and is bounded on the west by French Somaliland and Ethiopia, on the south by Ethiopia, and on the east by Somaliland. Its area of 68,000 square miles is 16 per cent larger than that of England and Wales, though the population is only some 750,000. The rainfall varies considerably from district to district and from season to season, but representative figures are 2 to 6 inches in the east, and 10 to 20 inches in the west. Mean temperature range between 70°F and 108°F on the coast, and between 50°F and a little over 90°F on the high ground inland. Following the coast there is a line of hills rising to over 7,000 feet, but the ground then falls to the central plateaux (3,000 to 4,000 feet high), which gradually slope down towards the south-east. In the main it is a semi-arid area. On the coast all vegetation is dessicated by the hot and dry south-west monsoon, the 'Kharif', which occurs during the period May to October. But the area becomes more temperate inland, especially on the mountain chain, where there are well grown forests of juniper and box covering some 200 square miles.

The population consists almost entirely of native Somalis, with a few Indians in the capital, Hargeisa, and in the main port of Berbera. There are about a hundred Europeans in the country. The Somalis, who are Mohammedans, are divided into nine tribes, descended from Yemen Arabs. They are predominantly nomadic stockherders, and each tribe has its recognized grazing areas with permanent wells, around which are situated the headquarters of the tribe. There are, however, frequent disputes about grazing rights, and these are understandable enough, because when the rains fail or are scanty, grazing makes all the difference between life and death—certainly for the animals, and sometimes also for their owners. There are about 1¼ million camels, 1½ million goats and over 2 million sheep, and there are cattle in smaller numbers in the west. Something like 90 per cent of the population are engaged in stock raising, at which, under the special conditions of the country, they are undoubtedly expert. The remaining 10 per cent, the settled population, occupy the towns and villages, and carry on some cultivation, particularly of jowari (sorghum), which forms a staple food, and of vegetables and a little fruit—bananas and pawpaws. But the whole of the cultivated area occupies no more than a few square miles and, as yet, makes only a small, though important, contribution to the food supply of the country. Where there is a dependable supply of water, cultivation could be quite successful, and the land—much of which is inherently fertile—could then give a much better return than when it is simply left to provide random grazing for stock. Indeed, the jowari gives grain for human consumption and fodder for stock. Cultivation is being encouraged by the Agricultural and Veterinary Department of the government, though the extension of the cultivated area is opposed by the stockherders, who fear the loss of valuable grazing.

One must not suppose, however, that the whole of the country could, or should, be cultivated. Some 5 to 10 per cent could probably be cultivated immediately, and this proportion could be doubled or trebled by careful development. The best utilization of the land will be by a properly balanced distribution between crop-raising and grazing. At present it is overgrazed, and a major problem is to control grazing so as to give the soil some chance of improvement by allowing natural vegetation to become established; this would give shade for the grasses and other fodder plants, would hold the soil against the eroding action of wind and water and would prevent the rain from running off too rapidly. However, it should be borne in mind that the camels in particular, and to a less degree the goats and sheep, are the Somalis' insurance against starvation in dry periods, since these animals can brouse on desert shrubs.

On the Somaliland plateaux one is brought face to face with a disconcerting question: whether, in fact, one ought to develop the region, and thus change the way of life of this independent, healthy and happy people. When the seasonal rains occur, they have little need for the so-called necessities of modern civilization. The camels provide milk on which the men and boys live exclusively when they are on the move following the herbage from one district to another. Camels also provide transport for the huts, which consist of arches of galol roots (a species of acacia) covered with reed mats woven by the women. Women and children, when settled for some time, live on goats and sheep, which can also be exchanged for jowari. Little clothing is needed, except on the high ground in winter. Shoes are made from camel hides. Why then interfere with this idyllic existence which involves little, if any, hard labour and, though primitive, provides all the essentials?

But the picture changes completely when the rains fail: then starvation stalks the land, and the idyllic existence changes into a grim struggle for survival. Under present conditions, the small population of the country cannot maintain even itself without outside help in bad years, let alone contribute to the world's food supply—which is, after all, one of the principal aims of development.

The main problem, as in all arid areas, is to provide controlled water supplies in sufficient quantities and at the right places. The rivers, dry for long periods, are a menace when in spate. They rise quickly, and the water attains a depth of 6 to 8 feet, rushing down from the hills, eventually spreading over the country and eroding the land. What is needed above all is canalization of this water to prevent its loss and to minimize its damaging effects; and this could be followed by irrigation schemes. Wells could be bored, especially near the river beds, and the possibility of tapping underground water further away should be investigated.

Much of the water contains a high percentage of minerals. There are salt plains with their own peculiar vegetation, and regions where the water is

gypseous; but gypsum can be used to counteract the effects of salt water. Could not the two be combined to improve the land in this territory?

Road building is another necessity if trade is to be established to make the people less dependent on their own flocks and herds. This task will call for research to discover the best techniques and materials to be used.

There is great scope for the use of devices operated by solar energy and wind power—the former for heating water, for distillation, and perhaps for driving small engines, and the latter for water pumping, battery charging (for electric light), and other agricultural purposes. At present, wood or charcoal is used for heating and cooking, and practically no animal or mechanical power is used in agriculture. On the plateaux there are large quantities of deadwood in the form of small twigs and branches which have been lopped from the shrubs to enable the flocks to eat the foliage. Some of this wood could perhaps be used as fuel to drive a small steam engine (a suitable steam engine has recently been produced in Great Britain).

On the agricultural side, new crops—leguminous field crops, vegetables and fruits—can be introduced and advice can be given on farming methods. Uses must be found for the surplus camel milk, which now goes to waste in the rainy season; and the processing of hides and skins must be improved to increase their export value. Later, it might be possible to preserve crops at the more highly nutritive stage of their growth, in order to provide good stored fodder against times of shortage. Timber could be greatly increased if the stockherders could be persuaded to prevent their goats from eating the seedlings.

Medical and veterinary services are established in a small way at some village centres, and there are a few schools at Hargeisa and at some of the other main towns, but their number must be increased if the population is to take full advantage of new and improved methods.

Israel

Although it lies in the same wide belt of semi-arid land stretching from northern Africa into central Asia, Israel is in many ways unlike the two areas already discussed. Here development, intensively planned and supported by foreign capital on a large scale, is progressing rapidly. This progress is, in fact, essential if the greatly increased population resulting from immigration is to be fed, and if the country is to become self-supporting. As an example of what might be done elsewhere to utilize local resources more fully, Israel provides a very interesting study.

The country, which is a narrow strip of territory running for some 250 miles from north to south along the Mediterranean and tapering to a point where it joins the Red Sea on the Gulf of Aqaba, has a relatively wide variety of climates. There is a cool climate in Galilee to the north, and in the Judea

hills, a mild Mediterranean climate in the central coastal plain, subtropical heat in the Jordan valley, and desert aridity in the Negev in the south, which covers about half of the total area of Israel. As in many Middle Eastern countries, water for agriculture is a major problem but, fortunately, there is surplus water in the north and sufficient in the central area. But if agriculture is to succeed in the Negev, water must be brought in, or perhaps partly supplied from the underground sources which geological surveys and test borings have revealed. There is ample water for the demands of the country as a whole, but it needs to be distributed. Water is being brought south from the sources of the Jordan and from the wadis in the north by a main irrigation canal which can also take in water from the rivers which it crosses en route. Thus the northern Negev at least can be watered sufficiently to allow some agricultural development.

The present population of Israel is approximately 1½ millions, but it may eventually reach 2½ millions, of whom some 20 per cent will be employed in agriculture in the north (where there are fertile areas), in the central coastal area and in the Negev. The plantations of citrus fruits and the arable land are mostly in the centre, there are vineyards on the slopes of the Carmel range, and afforestation areas on the northern and central hills. Overhead spray irrigation is commonly practised on the coastal plain.

Development of the country to ensure the fullest utilization of its resources is undertaken by the state through its Research Council, the Hebrew University at Jerusalem, the Haifa Technical College, and the Agricultural Research Institute at Rehovoth.

With so much agricultural and industrial development in progress, it is inevitable that the problems should be many and varied. A few of the more interesting may be mentioned.

One problem arises from the use of a network of pipes to carry water supplies to Jerusalem and other areas. Corrosion of these pipes, which are expensive and difficult to replace, is a serious difficulty. It is being overcome by the method known as 'cathodic protection', the main feature of which is the application of a small electrical potential to the pipes.

Some of the coastal dunes are being brought under cultivation by planting lucerne and other deep-rooting plants which can utilize the underground water and thus prepare the ground for other, shallower-rooting crops. The formation and quantity of dew is being studied because of its possibilities as a source of water for agriculture; there is reason to believe that 'dew mounds' consisting of heaps of round stones piled round the roots of trees to retain the dew, were used in ancient times. In the Judea hills, terracing—probably some of the oldest in the world—is frequently found, but it now needs repair.

Agricultural settlements (*kibbutzim*) in which all the work is done on a community basis and the returns are shared equally between the members have been established in many parts, even in the northern Negev, and they

are proving successful in bringing new land under cultivation. Their agricultural activities are often supplemented by light industries which the communities organize to employ some of their members.

Geological surveys are being made to investigate the occurrence of underground water and minerals in the Negev. Manganese, copper and iron ores have been found in encouraging quantities, as well as mica and feldspar. Deposits of phosphatic rock have been found, and there are also large deposits of ceramic clays and glass sands, which are already being worked to provide the raw materials for factories in Beersheba and elsewhere.

At Eilat, the new port of Israel on the Red Sea, there is an experimental garden established to determine which trees, shrubs and other plants can be grown in this hot, dry district where most of the available water is saline. Research is being done into the possibilities of cultivating marine algae to provide a locally grown food supply at Eilat and similar districts.

An interesting branch of agriculture in Israel is fish-farming. Marine fishing is not sufficiently successful to supply the country's needs, and carp are raised in artificial ponds. In some dry areas where the land is impregnated with salt, this has been leeched by flooding, which, at the same time is utilized for fish-farming. This can be followed by the growing of crops.

The enormous task of building a road from Beersheba over the Negev desert to Eilat has been undertaken, as well as another from Beersheba to S'dom at the southern end of the Dead Sea, for the transport of potash and other minerals.

There are vast deposits of papyrus peat in the Lake Huleh region in the north, and research is needed to decide on the best way to use it—for agricultural purposes or as a fuel.

The provision of new houses to accommodate a million or more immigrants from different parts of the world is a major task, and research work is being done into the properties of various building materials to determine the most suitable and most economical construction.

Another serious problem is that of supplying power for development in the thinly populated areas. Israel depends upon imported fuels to run its power stations at Haifa, Tel Aviv and Jerusalem; moreover, distribution costs are high. Hence the possibilities of wind power are being studied. A wind survey is being made to discover especially windy areas, and experimental wind power installations are being tested.

Not least among the development problems in Israel is that of converting a heterogeneous immigrant population, unaccustomed to the cultivation of land, into agriculturists. This difficult task has been tackled successfully with the help of instruction in modern agricultural methods.

Haiti

The republic of Haiti, which gained its independence from the French 150 years ago, occupies an area of some 11,000 square miles and forms the western part of the Caribbean island of Hispaniola. It has a population of about 3½ millions, mostly of pure negro stock, but there is a large minority of partly French descent.

The country is mountainous, some of the peaks rising to over 8,000 feet; there are some extensive plains and a central plateau, and the long coast line is deeply indented. The climate is tropical and, although there are dry areas, rainfall for most of the country is ample for cultivation.

Haiti faces serious economic and social problems which, though somewhat different from those in the areas already discussed, are no less urgent. Its population, though happy and reasonably healthy, is poor and has only a low standard of living. The educational standard is also low; most of the people are illiterate, and housing and hygiene are both unsatisfactory.

The country is predominantly agricultural and, in the absence of any extensive mineral resources, is likely to remain so. Its most important products are coffee, sisal, cocoa, sugar cane, cotton, tobacco, timber, cocoanuts, bananas, cattle and palm oil. But the methods of agriculture are primitive and the yield is low. Until quite recently, there was little control of land utilization, with the result that the naturally fertile land was impoverished. The tendency was to cultivate one plot and move on to another when the crop yield fell. Forests have been denuded by the indiscriminate felling of trees and by wasteful methods of using the timber. These practices have resulted in excessive runoff of the water in the rainy seasons, with flooding and serious soil erosion.

It is not surprising, therefore, that the economy of the country is in urgent need of reorganization if sufficient food is to be supplied for the rapidly growing population. There is the usual drift of the rural population to the towns—Port-au-Prince, the capital, already has a population of some 200,000, many of whom dwell in slums.

Yet the country has bauxite deposits of importance, some manganese and copper ores, and lignite (of not very good quality). These minerals, in conjunction with the agricultural products, could be worked to provide a basis for industries. Fishing, which could contribute to the food supply, must also be extended and improved.

Apart from some hydroelectric potential, power resources are meagre, and the government is interested in the possibilities of using wind power for water pumping and for local power production. With adequate instruction, the population could doubtless exploit some of the natural resources to provide building materials for houses and, perhaps, for the construction of simple wind power machines.

Exports must, however, be developed in order to pay for the imports of equipment and materials necessary for development. More roads are also needed. At present, assistance is being given by the United Nations and its agencies, and by other international organizations.

India and Pakistan

In relation to these two countries the term 'underdeveloped' must be used with some qualification. It only applies to certain special areas or to some aspects of development. In so far as there are important hydroelectric resources which have not yet been exploited and the mechanical power at the disposal of the population is small, both countries are underdeveloped. Again, both have extensive arid or semi-arid areas which, if made more productive, would ease the problem of food supply. There are such areas in west Pakistan and in the adjoining Indian territory, including Rajasthan, East Punjab, Kutch and Saurashtra. The Rajputana desert is said to be increasing in area rapidly.

The main problem is, of course, water supply. In Pakistan, particularly, important irrigation schemes have been completed and others are under construction, but in India there is rather less scope for such river-fed schemes, and some areas must rely on water pumped from underground sources. In parts of the Rajasthan desert, for example, the water lies at a depth of only 40 to 50 feet, but the provision of power for pumping is the difficulty. At present bullocks and camels are used, but this is an expensive method in view of the quantity of fodder they consume and their depreciation. Power for this pumping might be provided by wind or perhaps solar energy. Hence investigations are being made by a wind power committee established for this purpose, and by the National Physical Laboratory in New Delhi, which is experimenting with the utilization of solar energy. Possibly both these natural sources of energy can supplement animal power to provide energy for lighting, heating, cooking, water distillation, and for other domestic and agricultural purposes. In the absence of other fuels, cow dung, which might be used as a valuable manure, was being burnt, so, to avoid this waste, a small solar cooker has been developed for general use in the rural areas. Saurashtra, a rapidly developing area, generates power for rural electrification in thermal power stations, but the coastal districts have strong winds, and wind-driven generators might well be used to supplement the thermal power generation.

In Pakistan, rain-making experiments have met with some success. At Quetta an agricultural meteorological station is to investigate various questions relating to the influence of local climatic conditions on plant growth. Research on this subject has been in progress for some years at the Meteorological Station at Poona.

CONCLUSION

In conclusion, it must be emphasized that problems of underdevelopment are not confined to any one type of area—arid, tropical or temperate. Brazil, for example, has a wide range of climatic and geographical conditions, and the problems vary from one part of the country to another. Even Great Britain and Ireland are not without their underdeveloped areas: in the highlands and islands of Scotland and in the west of Ireland, development work must be undertaken to improve conditions if further depopulation is to be prevented.

Undoubtedly the difficulties are many and great, and there is no panacea which could be applied to them all. Each area has its own peculiar problems which must be studied separately if the right solution is to be found. But there is perhaps one need that they all share—the need for data, scientific, technical and economic, which are the indispensable basis for any sound development plan. There is much therefore to be gained by a well organized exchange of information on an international scale.

PAGES FROM THE PAST

Tocqueville on Science in Democracy

Under the title 'Pages from the Past', Impact *will reproduce from time to time some of the more important writings on the relationship between science and society which have withstood the test of time.*

This first selection consists of the two chapters of de Tocqueville's Democracy in America *in which the author discusses the influence of democracy on the development of science. Although well over a century old (the first volume appeared in 1835, the second in 1840), the work is one of the greatest ever written, not only about America, but about the nature of democracy in general; and what de Tocqueville has to say about the influence of democracy on science still today contains a large part of truth. No doubt he underestimated to some extent the capacity of democracy to produce the highest type of scientific intellect; as he perhaps also underestimated the value which democracy would set upon 'the slower and deeper labours' of the intellect, in contrast to the excessive value it would attach to the more superficial conceptions. But he was correct in almost every other respect. He foresaw that in democracies there would be a far larger number of people enjoying sufficient opulence to indulge in the pursuits of the intellect than there were in aristocratic societies; that the number of those who cultivate science would become immense; and that, though the contribution of the individual might be smaller, the overall result would be very great; so that, though great inventors might be rare, great discoveries would be frequent.*

He also judged rightly that democracies would be tempted to seek the immediate and practical results of science at the expense of what would now be called fundamental science; and that therefore the efforts of the authorities ought to be directed towards supporting science for its own sake, for without this there can be no further progress.

The pages that follow constitute chapters IX and X of vol. II, which appeared in 1840. They are given in the original translation by Henry Reeve.

THE EXAMPLE OF THE AMERICANS DOES NOT PROVE THAT A DEMOCRATIC PEOPLE CAN HAVE NO APTITUDE AND NO TASTE FOR SCIENCE, LITERATURE, OR ART

It must be acknowledged that among few of the civilized nations of our time have the higher sciences made less progress than in the United States; and in few have great artists, fine poets, or celebrated writers been more rare. Many Europeans, struck by this fact, have looked upon it as a natural and inevitable result of equality; and they have supposed that if a democratic state of society and democratic institutions were ever to prevail over the whole earth, the human mind would gradually find its beacon lights grow dim, and men would relapse into a period of darkness.

To reason thus is, I think, to confound several ideas which it is important to divide and to examine separately: it is to mingle, unintentionally, what is democratic with what is only American.

The religion professed by the first emigrants, and bequeathed by them to their descendants, simple in its form of worship, austere and almost harsh in its principles, and hostile to external symbols and to ceremonial pomp, is naturally unfavourable to the fine arts, and only yields a reluctant sufferance to the pleasures of literature. The Americans are a very old and a very enlightened people, who have fallen upon a new and unbounded country, where they may extend themselves at pleasure, and which they may fertilize without difficulty. This state of things is without a parallel in the history of the world. In America then everyone finds facilities, unknown elsewhere, for making or increasing his fortune. The spirit of gain is always on the stretch, and the human mind, constantly diverted from the pleasures of imagination and the labours of the intellect, is there swayed by no impulse but the pursuit of wealth. Not only are manufacturing and commercial classes to be found in the United States, as they are in all other countries; but, what never occurred elsewhere, the whole community is simultaneously engaged in productive industry and commerce.

I am convinced that if the Americans had been alone in the world, with the freedom and the knowledge acquired by their forefathers, and the passions which are their own, they would not have been slow to discover that progress cannot long be made in the application of the sciences without cultivating the theory of them; that all the arts are perfected by one another; and, however absorbed they might have been by the pursuit of the principal object of their desires, they would speedily have admitted that it is necessary to turn aside from it occasionally, in order the better to attain it in the end.

The taste for the pleasures of the mind is moreover so natural to the heart of civilized man that among the polite nations, which are least disposed to give themselves up to these pursuits, a certain number of citizens are always to be found who take part in them. This intellectual craving, when once felt, would very soon have been satisfied.

But at the very time when the Americans were naturally inclined to require nothing of science but its special applications to the useful arts and the means of rendering life comfortable, learned and literary Europe was engaged in exploring the common sources of truth, and in improving at the same time all that can minister to the pleasures or satisfy the wants of man.

At the head of the enlightened nations of the Old World the inhabitants of the United States more particularly distinguished one, to which they were closely united by a common origin and by kindred habits. Among this people they found distinguished men of science, artists of skill, writers of eminence, and they were enabled to enjoy the treasures of the intellect without requiring to labour in amassing them. I cannot consent to separate America from

Europe, in spite of the ocean which intervenes. I consider the people of the United States as that portion of the English people which is commissioned to explore the wilds of the New World; while the rest of the nation, enjoying more leisure and less harassed by the drudgery of life, may devote its energies to thought, and enlarge in all directions the empire of the mind.

The position of the Americans is therefore quite exceptional, and it may be believed that no democratic people will ever be placed in a similar one. Their strictly puritanical origin—their exclusively commercial habits—even the country they inhabit, which seems to divert their minds from the pursuit of science, literature, and the arts—the proximity of Europe, which allows them to neglect these pursuits without relapsing into barbarism—a thousand special causes, of which I have only been able to point out the most important—have singularly concurred to fix the mind of the American upon purely practical objects. His passions, his wants, his education, and everything about him seem to unite in drawing the native of the United States earthward: his religion alone bids him turn, from time to time, a transient and distracted glance to heaven. Let us cease then to view all democratic nations under the mask of the American people, and let us attempt to survey them at length with their own proper features.

It is possible to conceive a people not subdivided into any castes or scale of ranks; in which the law, recognizing no privileges, should divide inherited property into equal shares; but which, at the same time, should be without knowledge and without freedom. Nor is this an empty hypothesis: a despot may find that it is his interest to render his subjects equal and to leave them ignorant, in order more easily to keep them slaves. Not only would a democratic people of this kind show neither aptitude nor taste for science, literature, or art, but it would probably never arrive at the possession of them. The law of descent would of itself provide for the destruction of fortunes at each succeeding generation; and new fortunes would be acquired by none. The poor man, without either knowledge or freedom, would not so much as conceive the idea of raising himself to wealth; and the rich man would allow himself to be degraded to poverty, without a notion of self-defence. Between these two members of the community complete and invincible equality would soon be established.

No one would then have time or taste to devote himself to the pursuits or pleasures of the intellect; but all men would remain paralysed by a state of common ignorance and equal servitude. When I conceive a democratic society of this kind, I fancy myself in one of those low, close, and gloomy abodes, where the light which breaks in from without soon faints and fades away. A sudden heaviness overpowers me, and I grope through the surrounding darkness, to find the aperture which will restore me to daylight and the air.

But all this is not applicable to men already enlightened, who retain their

freedom, after having abolished from among them those peculiar and hereditary rights which perpetuated the tenure of property in the hands of certain individuals or certain bodies.

When men living in a democratic state of society are enlightened, they readily discover that they are confined and fixed within no limits which constrain them to take up with their present fortune. They all therefore conceive the idea of increasing it; if they are free they all attempt it, but all do not succeed in the same manner. The legislature, it is true, no longer grants privileges, but they are bestowed by nature. As natural inequality is very great, fortunes become unequal as soon as every man exerts all his faculties to get rich.

The law of descent prevents the establishment of wealthy families; but it does not prevent the existence of wealthy individuals. It constantly brings back the members of the community to a common level, from which they as constantly escape: and the inequality of fortunes augments in proportion as knowledge is diffused and liberty increased.

A sect which arose in our time, and was celebrated for its talents and its extravagance, proposed to concentrate all property in the hands of a central power, whose function it should afterward be to parcel it out to individuals, according to their capacity.[1] This would have been a method of escaping from that complete and eternal equality which seems to threaten democratic society. But it would be a simpler and less dangerous remedy to grant no privilege to any, giving to all equal cultivation and equal independence, and leaving every one to determine his own position. Natural inequality will very soon make way for itself, and wealth will spontaneously pass into the hands of the most capable.

Free and democratic communities, then, will always contain a considerable number of people enjoying opulence or competency. The wealthy will not be so closely linked to each other as the members of the former aristocratic class of society: their propensities will be different, and they will scarcely ever enjoy leisure as secure or as complete: but they will be far more numerous than those who belonged to that class of society could ever be. These persons will not be strictly confined to the cares of practical life, and they will still be able, though in different degrees, to indulge in the pursuits and pleasures of the intellect. In those pleasures, they will indulge: for if it be true that the human mind leans on one side to the narrow, the practical, and the useful, it naturally rises on the other to the infinite, the spiritual, and the beautiful. Physical wants confine it to the earth; but, as soon as the tie is loosened, it will unbend itself again.

Not only will the number of those who can take an interest in the productions of the mind be enlarged, but the taste for intellectual enjoyment will

1. This is an allusion to the St.-Simonians. [Note by Editor.]

descend, step by step, even to those who, in aristocratic societies, seem to have neither time nor ability to indulge in them. When hereditary wealth, the privileges of rank, and the prerogatives of birth have ceased to be, and when every man derives his strength from himself alone, it becomes evident that the chief cause of disparity between the fortunes of men is the mind. Whatever tends to invigorate, to extend, or to adorn the mind, instantly rises to great value. The utility of knowledge becomes singularly conspicuous even to the eyes of the multitude: those who have no taste for its charms set store upon its results, and make some efforts to acquire it.

In free and enlightened democratic ages, there is nothing to separate men from each other or to retain them in their peculiar sphere: they rise or sink with extreme rapidity. All classes live in perpetual intercourse from their great proximity to each other. They communicate and intermingle every day —they imitate and envy one another: this suggests to the people many ideas, notions, and desires which it would never have entertained if the distinctions of rank had been fixed and society at rest. In such nations the servant never considers himself as an entire stranger to the pleasures and toils of his master, nor the poor man to those of the rich; the rural population assimilates itself to that of the towns, and the provinces to the capital. No one easily allows himself to be reduced to the mere material cares of life; and the humblest artisan casts at times an eager and a furtive glance into the higher regions of the intellect. People do not read with the same notions or in the same manner as they do in an aristocratic community; but the circle of readers is unceasingly expanded, till it includes all the citizens.

As soon as the multitude begins to take an interest in the labours of the mind, it finds out that to excel in some of them is a powerful method of acquiring fame, power, or wealth. The restless ambition which equality begets instantly takes this direction, as it does all others. The number of those who cultivate science, letters, and the arts, becomes immense. The intellectual world starts into prodigious activity; everyone endeavours to open for himself a path there, and to draw the eyes of the public after him. Something analogous occurs to what happens in society in the United States politically considered. What is done is often imperfect, but the attempts are innumerable; and although the results of individual effort are commonly very small, the total amount is always very large.[1]

It is therefore not true to assert that men living in democratic ages are naturally indifferent to science, literature, and the arts; only it must be acknowledged that they cultivate them after their own fashion, and bring to the task their own peculiar qualifications and deficiencies.

1. Here the French text reads: 'le résultat général est toujours très grand', which is hardly the same thing as 'the total amount is always very large'. [Note by Editor.]

WHY THE AMERICANS ARE MORE ADDICTED TO PRACTICAL THAN TO THEORETICAL SCIENCE

If a democratic state of society and democratic institutions do not stop the career of the human mind, they incontestably guide it in one direction in preference to another. Their effects, thus circumscribed, are still exceedingly great; and I trust I may be pardoned if I pause for a moment to survey them.

We had occasion, in speaking of the philosophical method of the American people, to make several remarks, which must here be turned to account.

Equality begets in man the desire of judging of everything for himself: it gives him, in all things, a taste for the tangible and the real, a contempt for tradition and for forms. These general tendencies are principally discernible in the peculiar subject of this chapter.

Those who cultivate the sciences among a democratic people are always afraid of losing their way in visionary speculation. They mistrust systems; they adhere closely to facts and the study of facts with their own senses. As they do not easily defer to the mere name of any fellow man, they are never inclined to rest upon any man's authority; but, on the contrary, they are unremitting in their efforts to point out the weaker points of their neighbour's opinions. Scientific precedents have very little weight with them; they are never long detained by the subtilty of the schools, nor ready to accept big words for sterling coin; they penetrate, as far as they can, into the principal parts of the subject which engages them, and they expound them in the vernacular tongue. Scientific pursuits then follow a freer and a safer course, but a less lofty one.

The mind may, as it appears to me, divide science into three parts.

The first comprises the most theoretical principles, and those more abstract notions, whose application is either unknown or very remote.

The second is composed of those general truths, which still belong to pure theory, but lead nevertheless by a straight and short road to practical results.

Methods of application and means of execution make up the third.

Each of these different portions of science may be separately cultivated, although reason and experience show that none of them can prosper long, if it be absolutely cut off from the two others.

In America the purely practical part of science is admirably understood, and careful attention is paid to the theoretical portion which is immediately requisite to application. On this head the Americans always display a clear, free, original, and inventive power of mind. But hardly any one in the United States devotes himself to the essentially theoretical and abstract portion of human knowledge. In this respect the Americans carry to excess a tendency which is, I think, discernible, though in a less degree, among all democratic nations.

Nothing is more necessary to the culture of the higher sciences, or of the more elevated departments of science, than meditation; and nothing is less suited to meditation than the structure of democratic society. We do not find there, as among an aristocratic people, one class which clings to a state of repose because it is well off; and another, which does not venture to stir because it despairs of improving its condition. Everyone is actively in motion; some in quest of power, others of gain. In the midst of this universal tumult—this incessant conflict of jarring interests—this continual stride of men, after fortune—where is that calm to be found which is necessary for the deeper combinations of the intellect? How can the mind dwell upon any single point, when everything whirls around it, and man himself is swept and beaten onward by the heady current which rolls all things in its course?

But the permanent agitation which subsists in the bosom of a peaceable and established democracy, must be distinguished from the tumultuous and revolutionary movements which almost always attend the birth and growth of democratic society. When a violent revolution occurs among a highly civilized people, it cannot fail to give a sudden impulse to their feelings and their opinions. This is more particularly true of democratic revolutions, which stir up all the classes of which a people is composed, and beget, at the same time, inordinate ambition in the breast of every member of the community. The French made most surprising advances in the exact sciences at the very time at which they were finishing the destruction of the remains of their former feudal society; yet this sudden fecundity is not to be attributed to democracy, but to the unexampled revolution which attended its growth. What happened at that period was a special incident, and it would be unwise to regard it as the test of a general principle.

Great revolutions are not more common among democratic than among other nations: I am even inclined to believe that they are less so. But there prevails among those populations a small distressing motion—a sort of incessant jostling of men, which annoys and disturbs the mind, without exciting or elevating it.

Men who live in democratic communities not only seldom indulge in meditation, but they naturally entertain very little esteem for it. A democratic state of society and democratic institutions plunge the greater part of men in constant active life; and the habits of mind which are suited to an active life, are not always suited to a contemplative one. The man of action is frequently obliged to content himself with the best he can get, because he would never accomplish his purpose if he chose to carry every detail to perfection. He has perpetually occasion to rely on ideas which he has not had leisure to search to the bottom; for he is much more frequently aided by the opportunity of an idea than by its strict accuracy; and, in the long run, he risks less in making use of some false principles, than in spending his time in establishing all his principles on the basis of truth. The world is not led by long or learned

demonstrations: a rapid glance at particular incidents, the daily study of the fleeting passions of the multitude, the accidents of the time, and the art of turning them to account, decide all its affairs.

In the ages in which active life is the condition of almost every one, men are therefore generally led to attach an excessive value to the rapid bursts and superficial conceptions of the intellect; and, on the other hand, to depreciate below their true standard its slower and deeper labours. This opinion of the public influences the judgment of the men who cultivate the sciences; they are persuaded that they may succeed in those pursuits without meditation, or deterred from such pursuits as demand it.

There are several methods of studying the sciences. Among a multitude of men you will find a selfish, mercantile, and trading taste for the discoveries of the mind, which must not be confounded with that disinterested passion which is kindled in the heart of the few. A desire to utilize knowledge is one thing; the pure desire to know is another. I do not doubt that in a few minds and far between, an ardent, inexhaustible love of truth springs up, self-supported, and living in ceaseless fruition without ever attaining the satisfaction which it seeks. This ardent love it is—this proud, disinterested love of what is true—which raises men to the abstract sources of truth, to draw their mother-knowledge thence.

If Pascal had had nothing in view but some large gain, or even if he had been stimulated by the love of fame alone, I cannot conceive that he would ever have been able to rally all the powers of his mind, as he did, for the better discovery of the most hidden things of the Creator. When I see him, as it were, tear his soul from the midst of all the cares of life to devote it wholly to these researches, and, prematurely snapping the links which bind the frame to life, die of old age before forty, I stand amazed, and I perceive that no ordinary cause is at work to produce efforts so extraordinary.

The future will prove whether these passions, at once so rare and so productive, come into being and into growth as easily in the midst of democratic as in aristocratic communities. For myself, I confess that I am slow to believe it.

In aristocratic society, the class which gives the tone to opinion, and has the supreme guidance of affairs, being permanently and hereditarily placed above the multitude, naturally conceives a lofty idea of itself and of man. It loves to invent for him noble pleasures, to carve out splendid objects for his ambition. Aristocracies often commit very tyrannical and very inhuman actions; but they rarely entertain grovelling thoughts; and they show a kind of haughty contempt of little pleasures, even while they indulge in them. The effect is greatly to raise the general pitch of society. In aristocratic ages vast ideas are commonly entertained of the dignity, the power, and the greatness of man. These opinions exert their influence on those who cultivate the sciences, as well as on the rest of the community. They facilitate the natural

impulse of the mind to the highest regions of thought, and they naturally prepare it to conceive a sublime—nay, almost a divine—love of truth.

Men of science at such periods are consequently carried away by theory; and it even happens that they frequently conceive an inconsiderate contempt for the practical part of learning. 'Archimedes', says Plutarch, 'was of so lofty a spirit, that he never condescended to write any treatise on the manner of constructing all these engines of offence and defence. And as he held this science of inventing and putting together engines, and all arts generally speaking which tended to any useful end in practice, to be vile, low, and mercenary, he spent his talents and his studious hours in writing of those things only whose beauty and subtilty had in them no admixture of necessity.' Such is the aristocratic aim of science: in democratic nations it cannot be the same.

The greater part of the men who constitute these nations are extremely eager in the pursuit of actual and physical gratification. As they are always dissatisfied with the position which they occupy, and are always free to leave it, they think of nothing but the means of changing their fortune, or of increasing it. To minds, thus predisposed, every new method which leads by a shorter road to wealth, every machine which spares labour, every instrument which diminishes the cost of production, every discovery which facilitates pleasures or augments them, seems to be the grandest effort of the human intellect. It is chiefly from these motives that a democratic people addicts itself to scientific pursuits—that it understands, and that it respects them. In aristocratic ages, science is more particularly called upon to furnish gratification to the mind; in democracies, to the body.

You may be sure that the more a nation is democratic, enlightened, and free, the greater will be the number of these interested promoters of scientific genius, and the more will discoveries immediately applicable to productive industry confer gain, fame, and even power on their authors. For in democracies the working class takes a part in public affairs; and public honours, as well as pecuniary remuneration, may be awarded to those who deserve them.

In a community thus organized it may easily be conceived that the human mind may be led insensibly to the neglect of theory; and that it is urged, on the contrary, with unparalleled vehemence to the applications of science, or at least to that portion of theoretical science which is necessary to those who make such applications. In vain will some innate propensity raise the mind toward the loftier spheres of the intellect; interest draws it down to the middle zone. There it may develop all its energy and restless activity, there it may engender all its wonders. These very Americans, who have not discovered one of the general laws of mechanics, have introduced into navigation an engine which changes the aspect of the world.

Assuredly I do not contend that the democratic nations of our time are destined to witness the extinction of the transcendent luminaries of man's intelligence, nor even that no new lights will ever start into existence. At the

age at which the world has now arrived, and among so many cultivated nations, perpetually excited by the fever of productive industry, the bonds which connect the different parts of science together cannot fail to strike the observation; and the taste for practical science itself, if it be enlightened, ought to lead men not to neglect theory. In the midst of such numberless attempted applications of so many experiments, repeated every day, it is almost impossible that general laws should not frequently be brought to light; so that great discoveries would be frequent, though great inventors be rare.

I believe, moreover, in the high calling of scientific minds. If the democratic principle does not, on the one hand, induce men to cultivate science for its own sake, on the other it enormously increases the number of those who do cultivate it. Nor is it credible that, from among so great a multitude, no speculative genius should from time to time arise, inflamed by the love of truth alone. Such a one, we may be sure, would dive into the deepest mysteries of nature, whatever be the spirit of his country or his age. He requires no assistance in his course—enough that he be not checked in it.

All that I mean to say is this: permanent inequality of conditions leads men to confine themselves to the arrogant and sterile research of abstract truths; while the social condition and the institutions of democracy prepare them to seek the immediate and useful practical results of the sciences. This tendency is natural and inevitable: it is curious to be acquainted with it, and it may be necessary to point it out.

If those who are called upon to guide the nations of our time clearly discerned from afar off these new tendencies, which will soon be irresistible, they would understand that, possessing education and freedom, men living in democratic ages cannot fail to improve the industrial part of science; and that henceforward all the efforts of the constituted authorities ought to be directed to support the highest branches of learning, and to foster the nobler passion for science itself. In the present age the human mind must be coerced into theoretical studies; it runs of its own accord to practical applications; and, instead of perpetually referring it to the minute examination of secondary effects, it is well to divert it from them sometimes, in order to raise it up to the contemplation of primary causes.

Because the civilization of ancient Rome perished in consequence of the invasion of the barbarians, we are perhaps too apt to think that civilization cannot perish in any other manner. If the light by which we are guided is ever extinguished, it will dwindle by degrees, and expire of itself. By dint of close adherence to mere applications, principles would be lost sight of; and when the principles were wholly forgotten, the methods derived from them would be ill pursued. New methods could no longer be invented, and men would continue to apply, without intelligence and without art, scientific processes no longer understood.

When Europeans first arrived in China, three hundred years ago, they found that almost all the arts had reached a certain degree of perfection there; and they were surprised that a people which had attained this point, should not have gone beyond it. At a later period they discovered some traces of the higher branches of science which were lost. The nation was absorbed in productive industry; the greater part of its scientific processes had been preserved, but science itself no longer existed there. This served to explain the strangely motionless state in which they found the minds of this people. The Chinese, in following the track of their forefathers, had forgotten the reasons by which the latter had been guided. They still used the formula, without asking for its meaning; they retained the instrument, but they no longer possessed the art of altering or renewing it. The Chinese, then, had lost the power of change; for them to improve was impossible. They were compelled, at all times and in all points, to imitate their predecessors, lest they should stray into utter darkness, by deviating for an instant from the path already laid down for them. The source of human knowledge was all but dry; and though the stream still ran on, it could neither swell its waters, nor alter its channel.

Notwithstanding this, China had subsisted peaceably for centuries. The invaders who had conquered the country assumed the manners of the inhabitants, and order prevailed there. A sort of physical prosperity was everywhere discernible: revolutions were rare, and war was, so to speak, unknown.

It is then a fallacy to flatter ourselves with the reflection, that the barbarians are still far from us; for if there be some nations which allow civilization to be torn from their grasp, there are others who trample it themselves under their feet.